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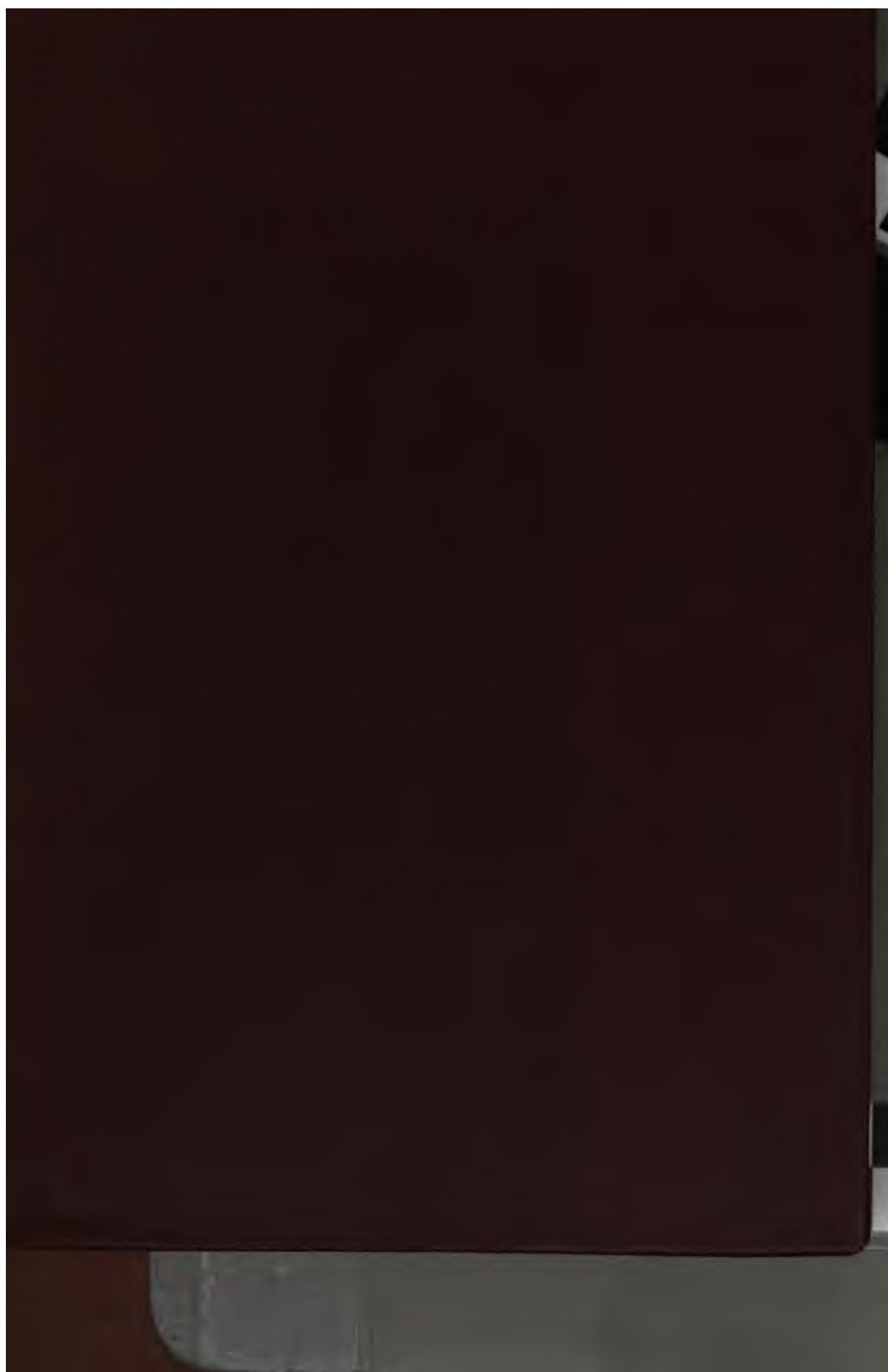
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THE  
NINTH ANNUAL REPORT  
OF THE  
AMERICAN RAILWAY  
Master Mechanics' Association,

*IN CONVENTION AT PHILADELPHIA,*

May 16th and 17th, 1876.

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WILSTACH, BALDWIN & CO.,  
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**AMERICAN RAILWAY**  
**MASTER MECHANICS' ASSOCIATION.**

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**OFFICERS FOR 1876.**

**PRESIDENT,**

**H. M. BRITTON, of Boston.**

**FIRST VICE-PRESIDENT,**

**N. E. CHAPMAN, of Cleveland.**

**SECOND VICE-PRESIDENT,**

**W. A. ROBINSON, of Canada West.**

**TREASURER.**

**S. J. HAYES, of Chicago.**

**SECRETARY,**

**J. H. SETCHEL, of Cincinnati.**

## REPORT.

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The Ninth Annual Convention of the American Railway Master Mechanics' Association assembled in the Hall of the Franklin Institute, in the city of Philadelphia, May 16th, 1876.

PRESIDENT H. M. BRITTON in the Chair, and the following officers present:

N. E. CHAPMAN, Cleveland & Pittsburgh R. R., FIRST VICE-PRESIDENT.

W. A. ROBINSON, Hamilton, Canada, SECOND VICE-PRESIDENT.

S. J. HAYES, Illinois Central R. R., TREASURER.

J. H. SETCHEL, Little Miami R. R., SECRETARY.

The session was opened with prayer, by the Rev. E. G. Brooks of Philadelphia.

On motion of Mr. R. Wells, the minutes of the last session were received and approved without reading.

THE PRESIDENT—The first business in order is the calling of the roll, after which any persons present entitled to membership will have an opportunity to sign the Constitution.

The Secretary called the roll, and the following persons answered to their names:

NAME.	ROAD.	ADDRESS.
BRITTON, H. M.	New York & New England	Boston, Mass.
BOON, J. M.	Pittsburgh, Fort Wayne & Chicago	Fort Wayne, Ind.
BUSHNELL, E. W.	Burlington, Cedar Rapids & Minn.	Cedar Rapids, Iowa.
BROOKS, H. G.	Brooks Locomotive Works	Dunkirk, N. Y.
CHAPMAN, N. E.	Cleveland & Pittsburgh	Cleveland, Ohio.
COOLIDGE, G. A.	Fitchburg	Charlestown, Mass.
COOPER, H. L.	Indianapolis, Bloomington & Western	Urbana, Ill.
CHURCH, FOSTER	Troy & Boston	Troy, N. Y.
CLARKE, PETER	Northern of Canada	Toronto, Canada.

NAME.	ROAD.	ADDRESS.
DEVINE, J. F.	Wilmington & Weldon	Wilmington, N. C.
DRIPPES, ISAAC	Pennsylvania	No. 3,405 Walnut Street, Philadelphia.
EDDY, WILSON	Boston & Albany	Springfield, Mass.
EASTMAN, J. U.	Nashville & Chattanooga	Nashville, Tenn.
ELLIS, J. C.	Schenectady Locomotive Works	Schenectady, N. Y.
ELLIS, W. H.	Philadelphia & Reading	Catawissa, Pa.
FRY, HOWARD	Philadelphia & Erie	Williamsport, Pa.
FINLAY, L.	Cairo & Fulton	Little Rock, Ark.
FUNK, J. S.	Northern Central	Marysville, Pa.
FOSTER, W. A.	Fitchburg, V. & M. Division	Fitchburg, Mass.
GRAHAM, CHARLES	Lackawanna & Bloomsburg	Kingston, Pa.
GARFIELD, E.	Hartford, Providence & Fishkill	Hartford, Conn.
GABBETT, H. D.	Pennsylvania	West Philadelphia, Pa.
GRANGER, W. E.	Albany & New England	Springfield, Mass.
GOULD, A.	New York Central & Hudson River	Rochester, N. Y.
HAYES, S. J.	Illinois Central	Chicago, Ill.
HUDSON, W. S.	Rogers Locomotive Works	Paterson, N. J.
HOLLISTER, C. W.	Valley	Hartford, Conn.
HILL, RUFUS	Camden & Atlantic	Camden, N. J.
HAGGETT, J. C.	Dunkirk, Allegheny Valley & Pittsburgh	Dunkirk, N. Y.
HARDING, B. B.	Raleigh & Gaston	Raleigh, N. C.
JOHANN, JACOB	Toledo, Wabash & Western	Springfield, Ill.
KIDDER, B. H.		Buffalo, N. Y.
KING, ROBERT	Charlotte, Columbia & Augusta	Columbia, S. C.
LAUDER, J. N.	Northern New Hampshire	Concord, N. H.
LANNON, WILLIAM	Western Maryland	Union Bridge, Md.
McALLISTER, W.	West Jersey	Camden, N. J.
McDOUGAL, B.	Mobile & Ohio	Whistler, Ala.
PHILBRICK, J. W.	Maine Central	Waterville, Maine.
RICHARDS, GEORGE	Boston & Providence	Boston, Mass.
ROBINSON, W. A.		Hamilton, Canada.
SOMERS, A. H.	Pittsburgh, Fort Wayne & Chicago	Valparaiso, Ind.
STRODE, JAMES	E. & C. Division Northern Central	Elmira, N. Y.
SELLERS, MORRIS		No. 6 Ashland Block, Chicago.
SETOHEL, J. H.	Little Miami	Cincinnati, Ohio.
SMITH, W. T.	Philadelphia & Erie	Erie, Pa.
SEDGLEY, JAMES	Lake Shore & Michigan Southern	Cleveland, Ohio.
STRONG, W. M.	New York & Harlem	New York City.
SANBORN, A. J.	Indianapolis & St. Louis	Mattoon, Illinois.
STEARNS, W. H.	Connecticut River	Springfield, Mass.
SPEAGUE, H. N.	Porter, Bell & Co.	Pittsburgh, Pa.
STRATTON, G. W.	Pennsylvania	Altoona, Pa.
THOMPSON, J.	Pittsburgh, Fort Wayne & Chicago	Crestline, Ohio.

NAME.	ROAD.	ADDRESS.
THOMPSON, J.	Eastern	Boston, Mass.
TAYLOR, J. K.	Old Colony & Newport	Boston, Mass.
UNDERHILL, A. B.	Boston & Albany	Boston, Mass.
VANBUSKIRK, W. G.	Dutchess & Columbia	Fishkill, N. Y.
WARREN, B.	St. Louis, Alton & Terre Haute	St. Louis, Mo.
WELLS, REUBEN	Jeffersonville, Madison & Indianapolis	Jeffersonville, Ind.
WIGGINS, J. E.	Missouri, Kansas & Texas	Hannibal, Mo.
WILDER, F. M.	Erie	Buffalo, N. Y.
WILLS, J. C.	Toledo, Wabash & Western	Lafayette, Ind.
WOODCOCK, W.	Central of New Jersey	Elizabethport, N. J.
WHITE, J. L.	Evansville & Crawfordsville	Evansville, Ind.
WILLIAMS, E. H.	Baldwin Locomotive Works	Philadelphia, Pa.
WEAVER, D. S.	Eastern Kentucky	Hunnewell, Ky.

#### ASSOCIATE MEMBERS.

FORNEY, M. N.	Railroad Gazette	New York City.
NOTT, GORDON H.		Boston, Mass.
SELLERS, COLEMAN		Philadelphia, Pa.

**THE PRESIDENT**—There will now be an opportunity for those who are eligible to become members to sign the Constitution. The Secretary will read Article IV of the Constitution relative to membership.

#### ARTICLE IV.

**SECTION 1.** The following persons may become members of the Association by signing the Constitution, or authorizing the President or Secretary of the Association to sign for them, and pay the initiation fee of one dollar: Any person having charge of the Mechanical department of a Railway known as "Superintendents," or "Master Mechanics," or "General Foremen," the names of the latter being presented by their superior officers for membership; also two Mechanical Engineers or the representative of each Locomotive Establishment in America.

**SEC. 2.** Civil and Mechanical Engineers and others whose qualifications and experience might be valuable to the Association may become Associate Members by being recommended by three active members. Their names shall then be referred to a committee, which shall report to the Association on their fitness for such membership. Applicants to be elected by ballot at any regular meeting of the Association, and five dissenting votes shall reject. The number of Associate Members shall not exceed twenty. Associate Members shall be entitled to all the privileges of active members excepting that of voting.

THE PRESIDENT—It has been customary heretofore for the President to read an address to the Association, but this year I will be obliged to apologize, for I have prepared nothing on account of business engagements. The next business in order will be the reading of the Secretary's report, but I will first call upon the Secretary to read a communication containing a resolution adopted at a late meeting of the Franklin Institute.

The Secretary then read the following :

Mr. COLEMAN SELLERS:

*Dear Sir*—I received your note in reference to the meeting of the American Railway Master Mechanics' Association, and at the meeting held last evening the following resolution was unanimously adopted :

*Resolved*, That the Secretary of the Franklin Institute be directed to invite the American Railway Master Mechanics to the Institute during their session in May, and that the Hall of the Institute be placed at their disposal for their meetings, if it can be so arranged as not to interfere with any of the uses or engagements of the Institute.

The only engagements of the Hall during May are the evenings of the third and seventeenth days of the month, and I trust these will not interfere with the meetings of the Association.

Yours truly,

J. B. KNIGHT, *Secretary*.

HALL OF FRANKLIN INSTITUTE, Philadelphia, March 16, 1876.

Mr. COLEMAN SELLERS, of Philadelphia—It was intended not only as an invitation to use this room, but to give to the Association the use of the Institute generally; and the clause that it shall not interfere with any of the meetings of the Institute, referred to the regular monthly meeting, which is on Wednesday evening of this week, to which all the members of the Convention are invited. At all other times I believe the Hall is at your disposal.

Mr. ROBINSON, of Canada—I move that a vote of thanks be tendered to the Franklin Institute for the very kind and generous manner in which they have met us and welcomed us to this Hall.

Carried.

THE PRESIDENT—The next business in order is the report of your Secretary.

### SECRETARY'S REPORT.

*To the American Railway Master Mechanics' Association:*

GENTLEMEN—According to the usual custom a detailed statement of membership, financial condition, and matters of general interest to the Association is herewith submitted.

## MEMBERSHIP.

At the Eighth Annual Meeting there was an addition of sixteen members, and eight have been admitted since that time according to the provision of our Constitution, making in all twenty-four new members.

During the year seven have withdrawn from the Association and twenty-nine have been dropped from our rolls for delinquency in paying their dues.

In this connection I regret exceedingly to be under the necessity of reporting to you the death of E. PIERCE, one of our most valued associates, who was for a number of years Master Mechanic of the Pittsburgh, Cincinnati & St. Louis Railroad, at Dennison, Ohio, and a worthy member of this Association.

With these changes the Association now numbers two hundred and twenty-eight members, twelve of which are Associate members.

## ANNUAL REPORTS.

The General Supervisory Committee ordered fifteen hundred copies, the usual number, of the Eighth Annual Report, which were printed at a cost of sixty-one and three-fifth cents each. Of these eight hundred and forty-one have been distributed to members, and one hundred and thirty-one to miscellaneous parties, fifty-six of which were sold, making nine hundred and seventy-two in all. There has also been forty-one copies of other reports distributed, and we still have on hand eighteen hundred and forty-seven miscellaneous reports, of which six hundred and ninety-two have been placed for sale in the hands of the Railroad Gazette.

## FINANCIAL.

The receipts of the Association have been as follows :

From Assessment .....	\$2,010 00
“ Initiation .....	25 00
“ Sale of Reports.....	56 30
“ Railroad Gazette for use of MSS.....	50 00
By donation of W. W. Evans.....	5 00
Total.....	<u>\$2,146 30</u>

For all of which I hold the Treasurer's receipts. There is due the Association from delinquent members \$340.

The Boston fund has been invested by the Trustees in three \$1,000 bonds of 1867, paying therefor \$1.20½ or \$3,615 for the three. The remainder of the principal and interest is invested with the President of the Lafayette Bank of Cincinnati, at six per cent. interest, with the intention of purchasing other bonds when the interest shall have accumulated to a sufficient amount. The bonds are deposited with the Safety Deposit Company of Cincinnati. The note for \$106.79, and the bill of sale for bonds, are in the hands of the Trustees, and are submitted with this report. The fund at this date, exclusive of the interest payable in July, amounts to \$3,726.79.

All of which is respectfully submitted,

J. H. SETCHEL, *Secretary.*

On motion, the report was received and filed.

THE PRESIDENT—The next business in order is the report of the Treasurer, which will be read by the Secretary.

# TREASURER'S REPORT.

MAY 15th, 1876.

S. J. HAYES, *Treasurer, in account with*

## AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.

1875.		Dr.	1875.		Cr.
May 12	To Balance on hand.....	\$23 13	May 15	By J. H. Setchel, Sec., Voucher No. 1,	\$750 00
May 15	" Cash from Secretary.....	1,187 00	June 10	" Reporter, " 2,	236 25
Aug. 2	" " ".....	33 75	Aug. 2	" Wilstach, Baldwin & Co., " 3,	33 75
Sept. 20	" " ".....	172 45	Sept. 20	" " " 4,	375 33
1876.			1876.		
Mar. 15	" " ".....	10 00	Mar. 14	" " " 5,	410 00
Mar. 15	" " ".....	410 00	May 12	" " " 6,	266 12
May 12	" " ".....	266 12	May 13	" J. H. Setchel, postage, " 7,	56 98
May 13	" " ".....	56 98		" Balance on hand.....	41 00
May 13	" " ".....	10 00			
		\$2,169 43			\$2,169 43

Which is respectfully submitted,

S. J. HAYES, *Treasurer.*



On motion, the Treasurer's report was received.

THE PRESIDENT—As neither of the Finance Committee are present, I will appoint Mr. Garfield, Mr. Richards, and Mr. Hollister as a Committee of Finance to examine the reports of the Secretary and Treasurer, and report this afternoon if possible. The next business in order is the report on Locomotive Tests, but as Mr. Forney, Chairman of the Committee, is not here and his report has not been received, the next thing in order will be the report of the Committee on the Construction of Locomotive Engines, which the Secretary will now read.

### **Report of the Committee on the Construction of Locomotive Engines.**

*To the American Railway Master Mechanics' Association :*

GENTLEMEN—Your Committee, to whom was delegated the subject of "Improvements in Locomotive Construction," promptly issued a circular embracing inquiries for improvements in "The Form and Construction of Locomotive Boilers, with reference particularly to the Economy of Fuel ; Valve and Machinery for working them ; Locomotive Trucks ; Spark Arrester or Smoke Consumer ;" also calling for the results of experience with engines of either Fairlies' or Forney's designs ; and a general inquiry for any improvements in the construction of engines, or parts of engines, of positive value, the knowledge of which would be of value or interest to our fraternity ; explaining that the value of the report would depend entirely upon the information received. In answer to this circular but twelve replies have been received ; the tenor of which implies but little progress toward the remedy of seeming defects in our present construction, or a general belief that if we can not achieve perfection we have at least results very satisfactory at present.

Your Committee respectfully report that they are in possession of no information that promises any real improvements in the form or construction of boilers, or in valves, or machinery for working the latter.

In reference to the construction of locomotive trucks, your Committee were favored with a report from Mr. Wells of the Jeffersonville, Madison & Indianapolis Railroad, submitting a sketch of a device in use by him, with drivers spread eight and a half feet, but your Committee were not agreed that the sketch submitted was that of a new device.

## SPARK ARRESTER.

The only information received in reply to our query for a perfect spark arrester, is contained in replies from Mr. Coolidge of the Fitchburg Railroad, and Mr. Hill of the Camden & Atlantic Railroad. Mr. Coolidge states that fifteen locomotives in his charge are fitted with what is generally known as the Hawkes' and Paine's Spark Arrester and Smoke Consumer. The style of smoke stack being simple in construction, in appearance resembling the Griggs and Diamond pattern, with the exception that it is larger; the straight part or waist being twenty-one inches in diameter, and the larger part containing the wire cloth forty-eight inches in diameter, with an opening at the top of twenty-two or twenty-four inches. This spark arrester has what is commonly known as an inside pipe, surmounted by a cone eighteen inches in diameter, which operates as a deflector, throwing the sparks or cinders into the space between the inside and outside pipes, from whence they are carried by two short tubes from the base of the smoke stack into two horizontal tubes, three inches in diameter, placed in the bottom of the boiler, from whence they are carried to the fire box, which they enter at points immediately under the fire-brick arch. The first spark arrester of the above description commenced service in July, 1872, the other fourteen have been applied at different times since; and, though operating very satisfactory, I can not claim for them perfection.

Mr. Hill, of the Camden & Atlantic Railroad, describes his invention in use on that road, and secured by letters patent, as follows:

"A deflecting plate is arranged in the smoke box, near the flue sheet, so as to cover the top flues, and extending downward toward the bottom of the smoke box. A steel-wire netting is placed in front of the said deflecting plate to confine the circulating sparks from passing to the open air, or coming in contact with the exhaust steam; a straight pipe without any obstruction is used for a smoke stack. The sparks after falling to the bottom of the smoke box come in contact with an injector, operated with a bell crank and rod, under the control of the engineer; the power used to operate the injector is a small portion of exhaust steam which can not be noticed by an expert. From the mouth of the injector a pipe is so arranged as to convey the sparks and steam to the fire box; the moist steam

used being of a low temperature readily combines with the smoke and gases, thereby supplying a deficiency needed to ignite them. Instead of admitting cold air into the furnace warm moist steam is admitted; the netting, to insure against clogging while on the road, is provided with a striker under control of the fireman and operated from the cab of the engine, the whole arrangement requiring no attention whatever while running."

Mr. Hill explains to your Committee that the company he represents are burning bituminous coal, and running fast and heavy passenger trains through a country thickly covered with pine and scrub oak, easily fired during the summer months; that previous to the perfection of his device they were constantly firing the woods, causing much damage to property and annoyance to passengers; that the use of his device has secured immunity from setting fires, not only arresting but perfectly consuming the sparks and smoke, but also preventing the falling of fine dust upon the train, improving the steaming qualities of the engine and resulting in a saving of fuel; that it is easily applied and at a very moderate cost; has been in service a year, and he has been directed to apply it to all engines upon his road.

Mr. Hill cordially invites an examination from all interested.

#### ENGINES OF FAIRLEE'S OR FORNEY'S DESIGN.

Mr. Wilder of the Erie Railway reports having one of the Fairlee engines, designed by William Mason, running upon the Erie Road, short trips between Buffalo and the International Bridge, and that the engine performs a very severe service, and does it successfully, though considerable trouble is experienced from leaky steam pipes, which difficulty he thinks purely a mechanical one, and could be easily overcome in construction. Not having the data of the cost of repairs, or fuel per ton per mile, etc., it is difficult for the Committee at present to arrive at any conclusion as to the comparative merits of the engine.

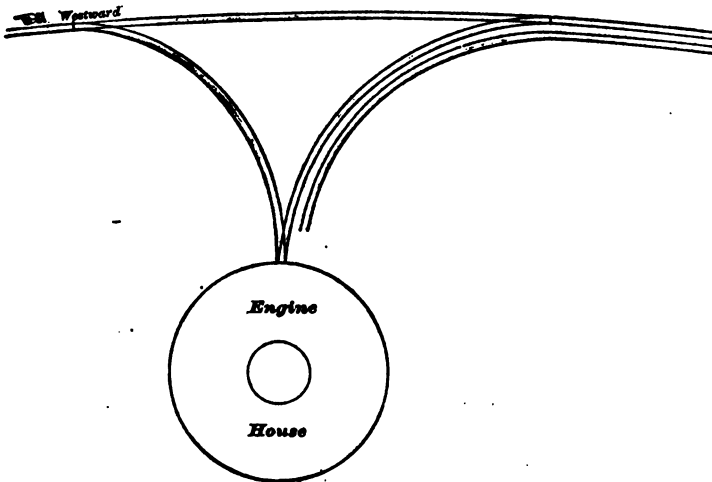
Mr. Wells reports the building of three engines, similar to those designed by Forney, for short runs for suburban passenger trains between Louisville and New Albany. They have proved successful for that purpose, yet he does not consider them suitable for general traffic.

Your Committee, in last year's report, referring to locomotives designed for very heavy work, recommended the class of engines known as Consolidation.

Since the report was written the Pennsylvania Railroad has adopted this class as its standard freight engine. This adoption by a leading railroad of a locomotive differing so widely in its dimensions from those generally used in ordinary freight service is undoubtedly a bold step in locomotive engineering, and it will certainly attract much attention. Your Committee have therefore collected as much information as possible relative to the comparative cost of running these and ordinary freight engines.

With reference to the loads hauled by these heavy engines, it may be well to say that no practical difficulties are experienced on the Pennsylvania Railroad and the Northern Central Railroad, level divisions, when hauling trains of from eighty to ninety loaded cars at fifteen miles an hour. These cars weigh about 18,000 pounds when empty, and their maximum lading is 28,000 pounds. These long trains are hauled round sharp curves, of which the radii range from 650 feet upwards. In exceptional cases very much sharper curves than this are passed; thus, on the Baltimore & Ohio Road, there is a *Y*, a tracing of which is attached, with curves of 136 feet radius,

**Tracing of "Y" on the Baltimore & Ohio R'd at Cumberland.**



and Consolidation Engines are run round these curves without trouble. In fact no difficulty has been reported in using them, in all cases, like ordinary freight engines.

The introduction of the Consolidation Engines for ordinary freight service is too recent for us to know what the effect on the cost of transportation will be. We have, however, collected some information which may help us to form an estimate, for any given railroad, of how some portion of this cost will be affected.

Accompanying this paper are statements furnished by the Lehigh Valley Railroad and by the Pennsylvania Railroad, which show how many cars can be hauled by Consolidation Engines over roads with certain controlling grades; what has been the cost for repairs, per engine mile, of Consolidation Engines when used on the mountain grades of the Lehigh Valley Railroad for coal trains, and as pushers on the heavy grades of the Pennsylvania Railroad; also the amount of stores used by these engines and the consumption of fuel per car mile.

To show some of the results to be expected from the use of Consolidated Engines the following estimates have been made, and submitted to the Association, not as established facts but as suggestions, which may possibly interest some of our members and which will, at any rate, indicate to us the importance of collecting fuller details of the cost of transportation so far as it is affected by modifications of the motive power.

Let us take, for example, one division of a railroad, say one hundred miles long, and which does a freight business during the year represented by 10,000,000 car miles. Let the controlling grades be taken at seventy feet to the mile. An ordinary ten-wheel engine will haul over such a road 15 cars, a Consolidation Engine will haul 25 cars. With 15 cars in train it would take 6,666 trips to perform the work of the division, allowing 100 miles as a day's work for train hands, an engineer at \$3.50, a fireman at \$2.00, a conductor at \$2.50, and three brakemen at \$2.00 each, makes \$14.00 per trip for train hands, or \$93,324.00 for train hands per annum. Taking 25 cars in train gives 4,000 trips or \$56,000.00 for train hands.

The cost of repairs, per mile, of ten-wheel engines at 6 cents per mile, for 666,600 miles, would be \$39,996.00; of Consolidation engines, at 8.5 cents per mile, for 400,000 miles, would be \$34,000.00.

Taking the saving of fuel at  $\frac{1}{10}$  pounds per car mile for the Consolidations, it would give a saving of 1,500 tons on the 10,000,000 car miles, or, say at \$3.00 per ton, \$4,500.00.

The interest on cost of power may be estimated thus: Allowing each engine to make 3,000 miles per month, it would take 18 ten-wheel or 11 Consolidation Engines, in working order during the year, to give the required service, allowing two engines, or about 11 per cent. of ten-wheel engines to be in shop for repairs, and three engines, or about 29 per cent. of the Consolidations for same reasons, we get 20 ten-wheeled or 14 Consolidations as the required number.

20 ten-wheel engines at \$9,000.00 each.....	\$180,000 00
Engine house room for 20 engines, say.....	20,000 00
	<u>\$200,000 00</u>
Capital invested for motive power in one case, and 14 engines	
\$11,000.00 each.....	\$154,000.00
Engine house room, say .....	14,000.00
	<u>168,000.00</u>
Showing a difference of.....	\$32,000.00

These savings in expenses by using Consolidation Engines amount to for one year:

For train hands.....	\$37,324.00
" repairs .....	5,996.00
" fuel .....	4,500.00
" six per cent. interest on capital.....	1,920.00
	<u>\$49,740.00</u>
Total. ....	\$49,740.00

Now, performing the same calculation for a moderately level division, with a few grades not over 20 feet to a mile and with a car mileage of say 20,000,000, we get a difference in favor of Consolidation Engines of \$45,296.00; the items of saving being:

Train hands.....	\$24,584.00
Repairs .....	6,672.00
Fuel .....	12,000.00
Interest on engines.....	2,040.00
	<u>\$45,296.00</u>
Total.....	\$45,296.00

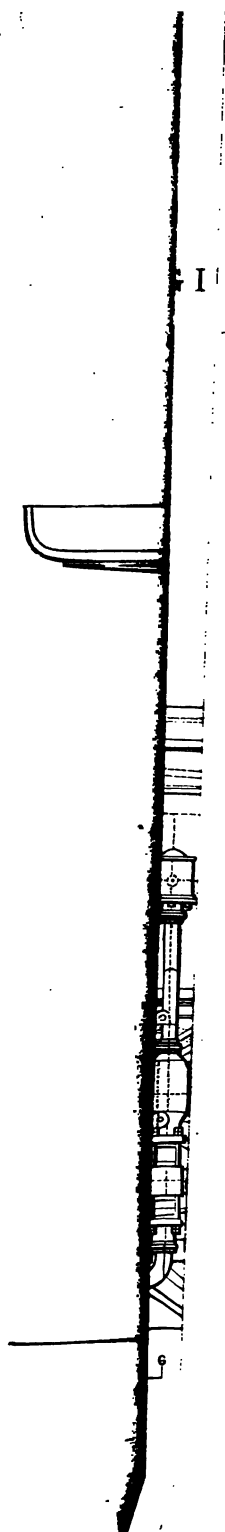
In making this estimate we have allowed one more brakeman for the train of eighty cars than for the train of forty-five.

The above estimates are based not on theoretical considerations of what the comparative duties of engines ought to be, but on actual results obtained under ordinary working conditions. The cost of repairs is based on an experience of six years, during which time the engines have been used as pushers on the Pennsylvania Railroad, where the duty is very severe and the mileage small, and on the Lehigh Valley Railroad as coal train engines over a mountainous grade. The consumption of fuel, per car mile, is based on an experience of only three months with nine engines, therefore the saving from this source can only be looked upon as an approximation, though the amount saved by the Consolidations is much less than the results shown on Table C might lead us to hope for.

The general dimensions of the Consolidation class are sufficiently familiar to make a detailed description unnecessary. They are essentially American in all their details, though, we believe, they have been exported by some of the locomotive builders to foreign countries. Their simplicity of construction forms a marked contrast to the complicated designs of engines for similar service by foreign builders.

We believe the first Consolidation Engine was designed by a member of our Convention, Mr. Alexander Mitchell, then of the Lehigh & Mahanoy Railroad. The designs were submitted to the Baldwin Locomotive Works, and were at that time considered so great a departure from ordinary practice that Mr. Mitchell had to assume the responsibility of the success of the engine. The officers of the railroad having the greatest confidence in Mr. Mitchell's judgment were guided by it, and the engine was built. At the completion of the first one the Lehigh & Mahanoy Railroad happened to be consolidating with the Lehigh Valley, and so the name "Consolidation" was suggested, which has since been adopted all over the country, for the merits of the engine on heavy grades was soon apparent, and large numbers of them were constructed by the various builders. They are now a recognized class of American engines.

Some alterations have, of course, been made since the first was built, which was in 1866, and we have attached to this report a







sketch of the engine, kindly furnished by the Baldwin Locomotive Works, which shows pretty plainly the general plan of construction of the most recently built locomotives.

TABLE A.—*Maximum Train of Loaded Cars. Average Weight of Car and Load 41,000 pounds.*

Controlling Grade.	Ten-Wheeled Engines.	Consolidation.
20 feet to the mile.....	45	80
70 " " " .....	15	25
96 " " " .....	.....	15
116 " " " .....	.....	12

TABLE B.—*Cost of Repairs and Stores per Mile.*

Engine.	Road.	Mileage.	COST PER MILE.		GENERAL AVE'GE.	
			Repairs.	Stores.	Repairs.	Stores.
J. M. Porter.....	L. V. R. R. \	164,808	7.8	2.6		
J. O. Stearns.....	"	147,432	9.4	2.6		
Mogul.....	"	90,375	4.5	2.1		
Tycoon .....	"	89,773	3.8	2.3		
Maryland .....	"	88,305	4.3	1.8		
Virginia .....	"	81,727	3.9	1.9	6.2	2.3
1092 .....	P. R. R.	154,980	9.9	1.2		
1111 .....	"	65,066	11.2	1.4		
1114 .....	"	82,913	10.0	1.2		
1115 .....	"	60,844	8.8	1.4		
1116 .....	"	66,180	8.1	1.3		
1131 .....	"	44,737	9.3	1.1		
1146 .....	"	36,961	5.8	0.9		
1147 .....	"	27,790	6.9	1.3		
1148 .....	"	43,120	5.2	0.7	8.9	1.2
1149 .....	"	66,326	6.6	0.6		
1150 .....	"	61,935	6.2	0.6	6.4	0.6

TABLE C.—Average Train and Consumption of Fuel per Car Mile.

Engines.	Road.	FEBRUARY, 1876.		MARCH, 1876.	
		Coal.	Cars.	Coal.	Cars.
113 .....	P. R. R.	5.0	25.9	4.7	28.5
72 .....	"	3.9	28.0	4.2	28.0
77 .....	"	4.1	26.5	4.4	28.3
85 .....	"	4.0	29.2	4.4	27.3
134 .....	"	4.5	25.4	4.3	29.5
213 .....	"	3.7	26.3	4.1	29.0
295 .....	"	4.0	26.9	4.3	25.8
1004 .....	"	3.8	33.2	4.2	33.2
1011 .....	"	2.7	55.0	2.7	59.0
		OCTOBER, 1875.		NOVEMBER, 1875.	
1149 .....	"	2.5	44.0	2.8	42.0
1150 .....	"	2.9	45.0	2.8	44.0

JAMES SEDGDLEY, }  
H. G. BROOKS, }  
W. S. HUDSON, } *Committee.*  
HOWARD FRY, }  
S. A. HODGMAN, }

THE PRESIDENT—If there is no objection the tables will not be read but will be printed with the report.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—I move that the report be received.

Carried.

THE PRESIDENT—Last year there was some action taken in reference to the discussion of reports; I think that they were set down for certain hours that all who wished might be present. This report may come under discussion now, or it may be deferred to some future time. If there is no objection it will be open now for discussion.

Mr. LAUDER, Northern New Hampshire Railroad—As there are none of the Committee that drew up the report present, it would be simple justice to them to delay the discussion. I do not know how the sessions are going to be held, but I would move that the discussion of this report be made a special order for this afternoon at four o'clock, provided the meetings are to be held as heretofore.

THE PRESIDENT—Our Constitution calls for but one session a day, from nine o'clock till two, and before that motion is in order it will be necessary to change the order of the meetings.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—I move that the discussion of this report be made the special order for to-morrow at eleven o'clock.

Carried.

THE PRESIDENT—There has been some talk about the time of our meetings. Quite a number of our members have suggested that we have two sessions a day instead of one; some think it would be better to adjourn at twelve and have an afternoon session; but our Constitution provides for but one session. What action will the Convention take in regard to it?

Mr. ROBINSON, of Canada—I think the members have all expressed themselves as being limited in time, in consequence of their arrangements to attend to certain duties which they feel called upon to perform in connection with the Centennial. They think we should devote our time to business first and give no attention whatever to any other duties until we get through with the business of the Convention. I think it a wise thought; for if we are to undertake any other duties we should go into them heartily, and it is the duty of all true American citizens to visit the Centennial exhibition. I will not call it a pleasure. I would move this resolution, and give the members a recess for five minutes in which to discuss it: That, in consequence of the limited time at the disposal of the members, two sessions be held each day until the completion of the business. The first from nine o'clock until twelve, and the second from two o'clock until five.

Mr. HAYES, Illinois Central Railroad—I second the resolution.

Mr. CHAPMAN, Cleveland & Pittsburgh Railroad—I move an amendment that the time be changed from one o'clock to four instead of from two o'clock to five.

THE PRESIDENT—There will now be a recess of five minutes for mutual consultation.

A recess of five minutes was then taken.

THE PRESIDENT—Mr. Robinson's has changed his resolution so as to read as follows:

*Resolved*, That, in consequence of the limited time at the disposal of the members, two sessions be held each day until the completion of business, viz.: from nine o'clock until one, and from two o'clock until five.

Mr. SETCHEL, Little Miami Railroad—Would it not be better to make the time between the morning and evening session shorter; we will not need all of that time.

Mr. ROBINSON, of Canada, I think one hour will be little enough time in which to get one's dinner at any of the hotels.

The resolution was adopted.

THE PRESIDENT—The report of the Finance Committee on the accounts of the Secretary and Treasurer is now ready.

### Report of Finance Committee.

*To the American Railway Master Mechanics' Association :*

GENTLEMEN—The Committee on Finance would respectfully report that they have examined the accounts of the Secretary and Treasurer, and find them correct.

E. GARFIELD,  
GEORGE RICHARDS, } Committee.  
C. W. HOLLISTER,

The report was adopted.

Mr. FORNEY, Railroad Gazette—During my absence from the hall I understand that the report of the Committee on Locomotive Tests was called for; I move that it be postponed until to-morrow, as there is an elaborate table accompanying it which is not ready.

THE PRESIDENT—Mr Forney the report has already been passed over and will not be called for until to-morrow. I would also say to the Convention that it would be well for a committee to be appointed early in the proceedings to suggest subjects for the consideration of the meeting next year, so that they can prepare themselves with subjects in good time. The next business in order is the report of the Committee on Locomotive Tire, Truck and Tender Wheels.

Mr. RICHARDS, Boston & Providence Railroad—We have no report this year.

THE PRESIDENT—The next business in order is the report of the Committee on the Best and most Economical Metal for Locomotive and Tender Bearings. The Committee consists of Messrs. Orton, Wilder, and Clarke. The report is in the hands of your Secretary.

### Report of Committee on the "Best and most Economical Metal for Locomotive and Tender Bearings."

*To the American Railway Master Mechanics' Association :*

GENTLEMEN—Your Committee, appointed at the last Annual Meeting to report on the Best and most Economical Metal for Locomotive and Tender Bearings, issued the following circular to each member of the Association :

#### *Circular of Committee on the "Best and Most Economical Metal for Locomotive and Tender Bearings."*

DEAR SIR—The undersigned were appointed at the last Convention of the American Railway Master Mechanics' Association, to report on the "Best and most Economical Metal for Locomotive and

"Tender Bearings," they therefore respectfully request that you will give them the benefit of your experience, and reply to the following questions as early as possible:

1. What composition of metals do you use on your railroad for engine driving axle-box bearings, what for engine truck bearings, and what for tender bearings?

2. Please give the length and diameter of journals, thickness of bearings, and the average mileage run per  $\frac{1}{16}$  of an inch in thickness of metal worn away in each of the above cases, and the amount of end play allowed to each class of bearings on axle journal?

3. What composition of metals do you use for connecting and coupling rod bearings?

4. Do you insert Babbitt or white metal in any of your bearings, and do you consider its use as of any advantage in reducing the frictional wear of either journals or bearings, and what form of recess in the bearings do you cut for receiving this metal?

5. Have you made any experiments in different alloys for journals, or other bearings, on locomotive engines?

6. Please state what these experiments were and the results attained.

7. From your experience what metal would you recommend for the different bearings on locomotive engines?

The Committee will also be glad to receive any additional information or suggestions pertaining to the above subject.

JOHN ORTTON, <i>Great Western of Canada,</i>	} Committee.
F. M. WILDER, <i>Erie,</i>	
PETER CLARKE, <i>Northern of Canada,</i>	

Fifteen members have responded to the circular.

For axle-box bearings five members use an alloy of six parts copper to one part of tin. One member uses five parts copper to one of tin, another uses six and a half to one, and another nine to one of copper and tin respectively. The remainder merely say they use "gun metal," or "hard brass," or brass lined with "white metal," without further specifying the mixture of the alloys.

Several of the members appear to use "Babbitt" or antifriction metal in a greater or less degree, the prevailing practice being to insert the Babbitt or white metal in recesses or grooves, varying

their lengths and widths in proportion to the sizes of the journals. One or two of the members use skeleton or shell brasses—having projecting ribs circled to fit the journals—and fill them with “white metal” so that the latter entirely forms the working surface of the bearing. Other of the members prefer solid brass without the use of any Babbitt for axle bearings.

For connecting and coupling rod bearings the alloy is mostly made of six or seven parts copper to one of tin, with Babbitt strips formed diagonally across the working surface of the bearing.

The following particulars will probably be interesting as exhibiting the different practices adopted by some of our members.

Mr. R. Wells, of the Jeffersonville, Madison & Indianapolis Railroad, says he uses “gun metal” for all bearings of engines and tenders; he inserts Babbitt metal in all bearings except for cross-head ends of main rods. The Babbitt is run into a recess on each side of center line of bearing, one inch wide for driving bearings, three-fourths of an inch wide for trucks, and half an inch wide for tender bearings, extending in length to within one inch of each end for driving, and within half an inch for truck and tender bearings. The space between the Babbitt strips is one and three-quarter inches for driving, one and a half inches for truck, and one and a quarter inches for tender.

Mr. Wells says he does not consider the Babbitt of any advantage in reducing frictional wear of journals; he thinks it rather increases it, but it aids in reducing the wear of the bearings and prevents the cutting of the journals, for which reason he recommends its use.

Mr. Wells gives the following sizes of journals as the standards on his road: Driving  $7\frac{7}{8} \times 6\frac{1}{2}$  inches, engine truck,  $8\frac{1}{8} \times 4\frac{3}{8}$  inches. Tender truck  $6 \times 3\frac{1}{2}$  inches. The end play allowed is  $\frac{1}{8}$  of an inch for engine bearings and  $\frac{1}{16}$  of an inch for tender bearings.

Mr. Jacob Johann, of the Western Division of the Toledo, Wabash & Western Railroad, says he uses for axle bearings a brass composed of:

Copper.....	85 per cent.
Tin .....	12.1 “
Zinc.....	2.9 “

These bearings have a dovetailed groove  $\frac{3}{4} \times \frac{1}{2}$  inch on each

side, running from end to end, filled with a white metal composed of:

Tin .....	89 per cent.
Antimony .....	7½ "
Copper .....	3¼ "

In the crown of the brass there is a cavity  $1\frac{1}{2}$  inches wide and  $\frac{3}{4}$  of an inch deep, extending in length to within  $\frac{3}{4}$  of an inch from each end. The object of this cavity is to equalize the wear on the body of the metal. For engine and tender truck bearings he uses brass "shells," lined with "white metal," to form a complete bearing surface. The composition of this lining metal is as follows:

Lead .....	67 per cent.
Tin .....	23 "
Antimony .....	10 "

Mr. Johann speaks strongly in favor of these bearings. He says they are not original with him, but he has had a long experience with them on other roads with as much satisfaction then as he is now having. As a proof of the superiority of this lined bearing over the plain solid brass bearing he writes thus:

"Relative to the value of this bearing I will mention but one case among many. Under one of our thirty-two ton passenger engines, on a regular run of one hundred and ten miles and return, there were two solid bearings which continually ran hot, causing much trouble and delay. I had the bearings removed and found the journals quite badly cut. This afforded an excellent opportunity for testing the 'shell' bearings. Without in any way mending the cut journals I replaced the solid bearings by the shells with white metal linings. During the first trip the boxes ran warm (not hot) for several miles and then gradually cooled. They gave no further trouble. Six or seven weeks after they were put in I inspected the journals, and found to my surprise that they were comparatively smooth. The bearings were not much worn and everything was in excellent condition. They have been running now for three months and have never been hot."

He further writes: "When I commenced my present engagement solid brasses were universally used on this division. During the summer months of 1875 hot boxes were the greatest source of an-

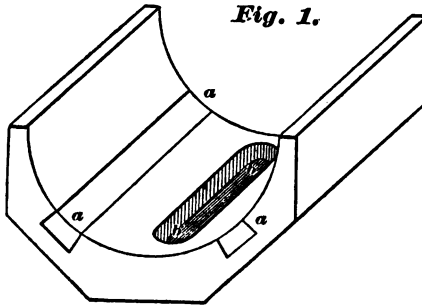


noyance connected with our passenger trains; it seemed impossible with any kind of lubricant to keep cool boxes. I was obliged to do something—I introduced these white metal bearings and the result was success. Hot boxes are now rare where before they were general."

**Mr. Jacob Johann's Method of Lining his Brasses—Toledo, Wabash & Western Railroad.**

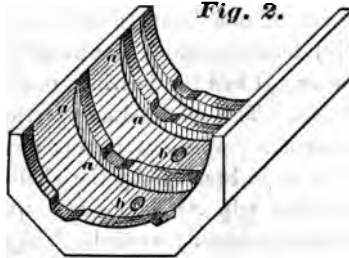
DRIVING AXLE BEARING.

*Fig. 1.*



ENGINE TRUCK SHELL.

*Fig. 2.*



Referring to the size of journals, the standard adopted on his road are driving  $8 \times 7$  inches, engine truck  $9 \times 5$  inches, and tender truck  $7 \times 3\frac{1}{2}$  inches. He allows for end play  $\frac{1}{8}$  of an inch for engine and  $\frac{1}{4}$  of an inch for tender bearings.

With respect to the size for engine truck journals, he remarks that since adopting the one,  $9 \times 5$  inches, he has had no trouble with hot boxes, the journals and bearings have worn better, and needed

fewer repairs, while the consumption of oil has been very much less than with smaller journals.

Neither Mr. Wells nor Mr. Johann give any data as to mileage run for any specific thickness of bearing worn away.

Mr. C. Graham, of the Delaware, Lackawanna & Western Railroad, Bloomsburg Division, mentions one case which recently came under his notice where the engine had run 178,000 miles and, the driving bearings (which were plain solid brass composed of copper and tin in the respective proportions of six to one) had only lost a full eighth of an inch from their original thickness, which gives about 80,000 miles run per one-sixteenth of an inch worn away. Mr. Graham says he uses no Babbitt metal except for connecting rod bearings, as he is doubtful that any advantage is gained from its use.

Mr. Woodcock, of the Central Railroad of New Jersey, says some of his engines have run 56,000 miles for one-sixteenth inch wear in thickness of driving bearings, and 15,000 miles for engine truck bearings. In the latter he uses Babbitt metal, but it does not appear that he uses it for driving bearings. His journals are  $8 \times 6\frac{1}{2}$  inches for driving,  $7\frac{1}{2} \times 4\frac{1}{2}$  inches for engine trucks, and  $6 \times 3\frac{1}{2}$  inches for tender trucks. The end play of his engine bearings is  $\frac{1}{8}$  and  $\frac{1}{4}$  of an inch for tenders. He thinks there is an advantage in the use of Babbitt, but can give no data as to economy.

Mr. P. Clarke, of the Northern Railway of Canada, prefers using plain brass, six parts copper to one part tin, for all engine axle bearings, although a number of his engines are running with Babbitted bearings. He considers Babbitt metal beneficial for rod bearings when properly applied in strips from end to end, because in that form it maintains the true outline shape of the bearings which is destroyed, generally, when the Babbitt is confined at the ends by the brass, as is the case of recesses filled in by Babbitt.

One great reason Mr. Clarke has for objecting to the use of Babbitt for axle bearings is because they are not easily got at to examine from time to time. He adopts the plan of recessing a cavity in the crown of his driving bearings as a means of preventing undue wear on the sides and the consequent "knocking" experienced as the bearings become worn. The average mileage his engines run per one-sixteenth inch wear of bearings, is for driving 30,000, for engine trucks 9,100, and for tender trucks 6,600 miles.

The sizes of journals are, driving  $8 \times 7$  inches, engine truck  $6\frac{1}{2} \times 4\frac{1}{2}$  inches, tender truck  $6 \times 3\frac{3}{8}$  inches. End play given is  $\frac{1}{2}$  of an inch for engines and  $\frac{1}{8}$  of an inch for tenders.

Mr. Ellis, of the Philadelphia & Reading Railroad, says he prefers the use of Babbitt for axle bearings on the score of economy, as some of his ten-wheel freight engines have run a distance of 14,000 miles with Babbitted bearings, as compared with only 10,000 miles when they were not Babbitted, for  $\frac{1}{8}$  of an inch reduction in thickness of bearings. He allows half an inch end play for tender bearings, but does not say what is allowed for engine bearings.

On the Great Western Railway of Canada, the practice in operation is to use only plain brass bearings composed of 5 parts copper to 1 of tin for axle bearings, and  $5\frac{1}{2}$  parts copper to 1 of tin for connecting and coupling rod bearings. These bearings work admirably, and a hot box or journal on any engine is almost unknown.

The average mileage, taken from several engines, per  $\frac{1}{8}$  of an inch wear of bearing, is 33,000 miles for driving and 24,000 for engine and tender truck bearings. Occasionally some of the truck and rod bearings have been Babbitted, but with no advantageous results.

The standard sizes of journals are, driving  $7\frac{1}{2} \times 7$  inches, engine truck  $8 \times 4\frac{1}{2}$  inches, and  $5\frac{1}{2} \times 3\frac{3}{8}$  inches for tender trucks. The end play usually allowed is  $\frac{1}{8}$ ,  $\frac{1}{8}$ , and  $\frac{1}{8}$  of an inch for each of these journals respectively.

Mr. F. M. Wilder, of the Buffalo Division of the Erie Railway, says the composition of all bearings is 6 of copper to 1 of tin.

He gives the following dimensions as the standards for their axle journals: Driving  $8 \times 7$  inches, engine truck  $10 \times 4\frac{1}{2}$  inches, and  $7 \times 3\frac{1}{2}$  inches for tender trucks.

He writes "Babbitt or antifriction metals are used on all rod connections, also in the driving box bearings. Our driving boxes are lined with gibs of brass or hard metal, one on top and one on each side, fitted perfectly into dovetailed grooves, leaving a space about  $1\frac{1}{2}$  inches wide, which is filled by Babbitt metal being cast in."

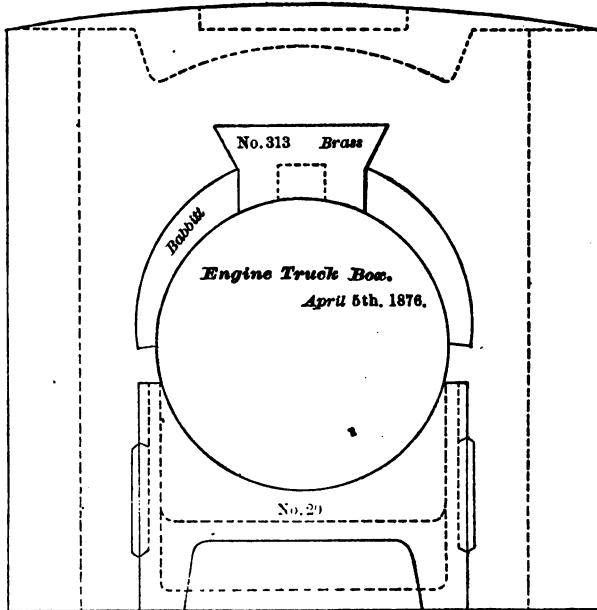
As a summary of the evidences received, your Committee think the majority favors hard brass, composed of 6 parts copper to 1 part tin, for all axle and rod bearings. The use of Babbitt is not generally adopted for driving axle bearings, but for truck and rod bearings it is more oftener used than not, although it does not appear to

give universal satisfaction. The fact generally admitted is that Babbitt tends to *lengthen* the life of the bearing, but it also tends to *shorten* the life of the journal.

Respectfully submitted,

JOHN ORTTON, *Great Western of Canada,* }  
F. M. WILDER, *Erie,* } *Committee.*  
PETER CLARKE, *Northern of Canada,* }

**Tracing showing Method of using Babbitt Metal in connection with the Brass in the Engine Truck Boxes—Central Railroad of New Jersey.**



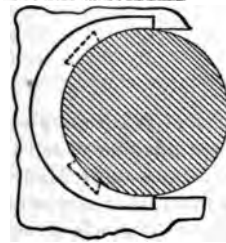
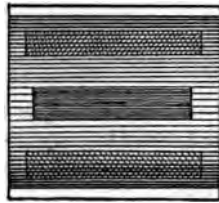
**THE PRESIDENT**—Is it your pleasure to have the subject brought before the Convention at this time or to have it deferred?

**Mr. WELLS**, Jeffersonville, Madison & Indianapolis Railroad—We might as well discuss this subject now as any time.

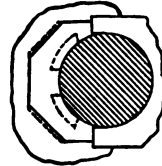
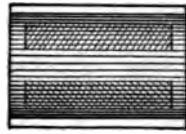
**THE PRESIDENT**—There is no objection to discussion at this time.

**Mr. WOODCOCK**, Central Railroad of New Jersey—There must be a difference in reference to the use of Babbitt metal on bearings. We have about come to the conclusion in using steel pins that it is essential to have

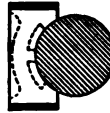
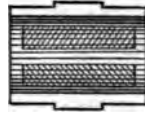
DRIVING BOX, TRUCK, AND TENDER BRASS, ATLANTIC & GREAT WESTERN R.R.



DRIVING AXLE.



TRUCK AXLE.



TENDER AXLE.



Babbitt metal in connection with them. Last summer in getting new engines we had solid brasses put in, and thought if we could we would get along without it, but we found that we had warm pins continually on passenger engines at high speed. We wrote to the Baldwin Locomotive Works, where the engines were built, and they said they had heard no reports of engines on other roads, made of the same material, having warm pins. We, to test the matter, had a set of brasses taken out and grooved and Babbitt metal inserted in each box; and, after putting these together and putting the engine on the same train, we found no difficulty and at once set to work on the new engines, and used that Babbitt, since which they have run satisfactorily. It may be that with an iron pin we might run them without Babbitt. There is a difficulty in using a steel pin; if a steel pin be polished ever so smooth, if it be examined with the microscope, it will be found to have rough edges; it can not be polished as a piece of iron. It seems that Babbitt metal has some effect to get better results. I would like to ask a question whether any of the members have used Babbitt on steel pins. We would like to hear from them. On our road we have adopted Babbitt metal; on driving brasses we do not use it, but on truck brasses we do. On cars we use solid brasses all through, and I believe our road is obtaining good results by this method.

Mr. FUNK, Northern Central Railroad—I have tried soft metal in various ways; I find it is of no use to an engine whatever. If we use it at all, why not use it in the driving bearings and brasses? On our road we had them out within two months after the engine commenced running; the pins warmed. At the time I took the Babbitt out one of the pins had no Babbitt in, and I had no trouble with that. Whenever I find boxes heating I take the Babbitt out and have no trouble whatever; and there is another thing, Babbitt costs nearly twice as much as brass does, and I came to the conclusion that brass was the cheapest of the two. I see no benefit in using it in any part of the locomotive. I have tried it for twenty-five years and know how it works.

Mr. CLARKE, Northern Railroad of Canada—I think if the brasses were made with the proper alloy there would be no trouble with steel pins. I have in mind several engines in which we use it with steel pins and we have no trouble with it.

Mr. WILDER, Erie Railway—I was speaking with Mr. Woodcock, who called attention to steel bearings, of the experience I have had on the whole line of the Erie Road. When I first came on the road we had steel bearings on the trucks, and it was almost impossible to prevent the engines from heating. I took the engine brasses off and put in soft metals, and had no difficulty after that in keeping the bearings from heating. With steel bearings it is better to have soft metal; it has been my experience in that regard. The gentleman was speaking about the crank pins heating; he says why not put it in the engine truck bearings and driving bearings? I

should say that on the driving pins there is more pressure than in any other part of the engine; the whole pressure is exerted on a very small space.

Mr. HILL, Camden & Atlantic Railroad—I have a considerable experience in bearings, and have tried solid brasses in various ways. Mr. Woodcock uses soft brasses to run that engine on the express train—I could not; I had to put Babbitt in all the bearings, and I used nine to one, and I find nine to one with Babbitt, inserted all the way across, requires less oil. I can run it in that way on an express train from four to six months, while without Babbitt I am continually filing after three to four trips. I have tried bronze bearings and find them very satisfactory. Under cars we use a brass shell, and an alloy composed of ten of lead to one of antimony, which we use exclusively on express trains. With proper lubrication I consider we get as good a bearing as can be produced. We are troubled a good deal with a very fine sand that absorbs our oil. Where a road has no dust to contend with you can probably use solid brasses.

Mr. ROBINSON, of Canada—I am very glad to hear so much discussion on this question. I have watched the subject of bearings for a great many years, and have often wondered why so large a proportion of the roads object to Babbitt metal, while another portion speak so favorably of it. I am inclined to think if we only knew the exact mixtures of the Babbitt metal these various opinions would not exist. What is called Babbitt by one is not the same called Babbitt by another. One gentleman remarked to me that he thought a soft metal was used chiefly to cover up some mechanical defect; a properly mixed composition of copper with a small portion of tin was as good as any other metal if the mechanical adjustment is sufficiently close, if not you require some soft metal to make up for that. In going around to some machine shops I have been amused to see a journal placed in a box and to see a workman take a pot of metal called Babbitt and pour that in. It must fit, of course, as a piece of lead in a mould. Something has been said about the use of lead; I believe lead has been largely used and called Babbitt metal. I do not think this body has done so. We notice among the most of the car builders that a large number of the bearings when taken from the sand are cleaned with some kind acid, and a thin sheet of lead is placed under that bearing, between that and the journal, and it has been found to work very successfully. Now what does that do? It seems to me that the lead polishes up the journal, fills up the little pores, and corrects whatever is defective in the iron by rubbing in a portion of the lead. Also in the brass; whatever was wrong in the casting was corrected by the portion of lead. The whole would go together with some kind of fit which satisfies the common cheap steam engine builder. I simply come back to my statement, that I believe the differences existing in that report are only apparent and not real. When we thoroughly understand the matter, after discussing it together, we find that there is a different admixture

of these metals which are all called the same thing. I like the remarks of Mr. Clarke where he speaks of placing the Babbitt metal right across the journal instead of only in the center. I have thought it was an injurious practice, this leaving a hard substance of brass on the outsides of the bearing thereby cutting into the journal where the journal is soft enough to receive it.

Mr. MACKENZIE, Hannibal & St. Joe Railroad—We are using a truck with journals five by nine; in June, 1872, a set of white metal bearings was put under that engine, and she made 93,000 miles before they gave out. They are steel journals; the wear was scant one-eighth of an inch. I took those metals out and replaced them with solid brass; she has now made eight or nine thousand miles and I find no difference in the running of the truck on white metal or brass on the steel journal.

Mr. HUDSON, Rogers Locomotive Works—I apprehend that a great deal of the difference of experience with what is called Babbitt metal, arises from the different compositions of the Babbitt metal; I have no doubt of that being the case. The best so-called Babbitt metal that I know anything about is a mixture of copper and tin; one part of copper and nine of tin. That makes a metal that wears well, that is not too soft nor too hard; but if you use what some call Babbitt metal, made of a little antimony and copper, and it wears different from the other and gives a bad name to the Babbitt metal I am not surprised. In regard to being able to run connecting rods without Babbitt metal I apprehend it is more a question of surface and pressure than anything else. I have no doubt that if we increase the amount of surface, as in ordinary brass bearings, we should be able to run brass or cast iron; but as we are compelled to do the work in the shortest possible length as best we can, with a short bearing, we must use metal that will stand it. If brass will not do it without cutting we interpose a soft metal. There is another effect of the soft metal, that while it prevents cutting into the brass to a great extent it cuts away the bearing very fast, it operates to hold the dirt that may get in, and the injury done to the bearing often more than counterbalances the saving.

On motion, the discussion on this subject was closed.

THE PRESIDENT—The business next in order is the report on Injectors.

The Secretary read the report as follows:

*To the American Railway Master Mechanics' Association:*

GENTLEMEN—Your Committee appointed to report upon the following subject,

**"Is it Economical to use Injectors upon Locomotives, and if so, to what extent?"**

beg leave to submit the following:

Circulars of inquiry were issued in the usual manner, and elicited fifteen replies from Master Mechanics in charge of 1361 locomotives,



of which 508 engines have pumps and injectors, 769 have pumps and no injectors, and 22 engines have injectors and no pumps.

The prevailing opinions expressed in the replies to our circular are:

1. Injectors are valuable auxiliaries to pumps on locomotive engines.
2. Injectors are not as reliable as pumps for feeding locomotive boilers.
3. There is no economy in fuel from the use of the injector.
4. The cost of construction and maintenance of pumps and injectors is about the same.

Your Committee could not learn of any careful experiments having been made for the purpose of determining the comparative reliability of pumps and injectors for engines in passenger and freight service, or which method of injecting the feed water involves the greater consumption of fuel.

Recognizing that reliability and economy in fuel are the main things to be considered, the Chairman of your Committee, Mr. E. T. Jeffery, conducted a series of experiments, with a freight engine on the Illinois Central Railroad, with the results given in the tables which form a part of this report.

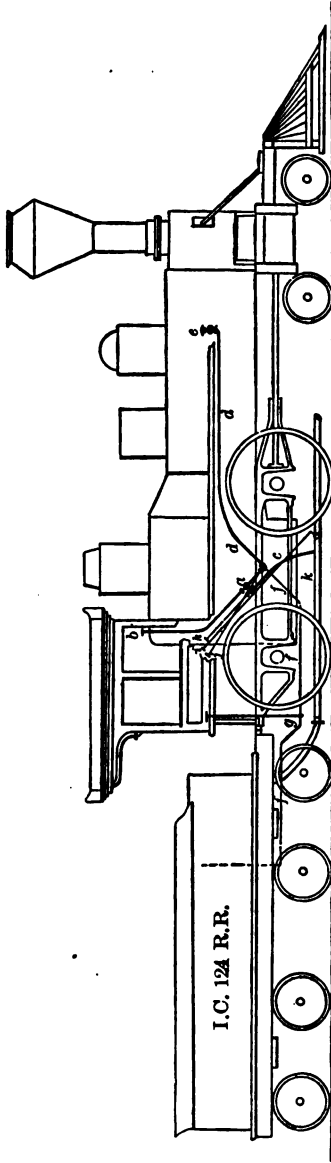
The engine used has 16×24 inch cylinders, 5 feet drivers, and weighs 67,900 pounds, of which 43,950 pounds is on the driving wheels.

The experiment consisted in running this engine eight trips, of 128 miles each, using her pumps exclusively, and the same number of trips, over the same piece of road in the same service, using an injector exclusively, thus making a total run of 1024 miles with the pumps and 1024 miles with the injector.

The pumps are of the ordinary full stroke pattern, with plunger two inches in diameter. The injector used was a No. 6 Friedman Injector, placed between the driving wheels on the right-hand side of the engine, as shown on the drawing which accompanies this report.

A competent person accompanied the engine during the whole time and weighed all the coal used, measured all the water, kept a record of the average number of cars in the train, the pressure shown by the steam gauge, etc.

# METHOD OF ATTACHING INJECTOR.



Cylinders, 16x24 inches.

Diameter of drivers, 68 inches.

Weight on drivers, 48,900 pounds.

Weight of engine, 67,900 pounds.

Weight of tender loaded, 45,600 pounds.

a, Injector.

b, Steam valve.

c, Suction pipe.

d, Injection pipe.

e, Injector check.

f, Relief pipe.

g, Regulating valve of relief pipe.

h, Valve regulating water supply to injector.

i, Stop cock of feed pipe to pump.

j, Overflow.

k, Feed pipe to pump.

The Chairman of your Committee desires to state that he gave positive instructions to the engineer, and the person selected to accompany the engine, to show no favor to pump or injector, but to let each stand on its merits. Every effort was made to have an impartial trial, and it is believed the object was attained.

The total amount of coal used while running with the injector was 69,892 pounds against 76,234 pounds while running with the pump, showing that the engine burned 6,342 pounds, or  $9\frac{8}{100}$  per cent. more with the pump than with the injector.

The total amount of water used with the injector was 374,610 pounds against 391,106 pounds with the pump, being an increase of 16,496 pounds of water, or  $4\frac{4}{100}$  per cent. with the pump.

The average number of loaded cars hauled while using the injector was  $22\frac{31}{100}$ , and while using the pump  $22\frac{96}{100}$ , being  $\frac{54}{100}$  cars, or  $2\frac{42}{100}$  per cent. more with the pump than with the injector.

The number of pounds of water evaporated by a pound of coal. was  $5\frac{36}{100}$  pounds with the injector, and  $5\frac{14}{100}$  pounds with the pump, being  $\frac{22}{100}$  pounds, or  $4\frac{28}{100}$  per cent. more with the injector than with the pump.

The total time the engine was in service with the injector was one hundred and two hours and fifty-five minutes, and with the pump one hundred and ten hours and five minutes, or seven hours and ten minutes longer than while using the injector. The total time consumed standing at stations was thirty-one hours and eighteen minutes with injector, and twenty-eight hours and twenty-three minutes with the pump, being two hours and fifty-five minutes longer with the injector than with the pump.

The total time consumed in switching at way stations was ten hours with the injector, and eighteen hours and fifty-five minutes with the pump, being eight hours and fifty-five minutes longer with the pump than with the injector.

The running time was sixty-one hours and thirty-seven minutes with the injector, and sixty-two hours and forty-seven minutes with the pump, being one hour and ten minutes longer with the pump than with the injector.

As already stated the engine used 6,342 pounds less coal while using the injector than while using the pump, but from this should be deducted a proper amount on account of the eight hours and

fifty-five minutes longer switching time at way stations while using the pump. It seems fair to allow 2,000 pounds of coal for this extra work, which reduces the saving to 4,342 pounds, or  $6\frac{31}{100}$  per cent. by using the injector. It should also be borne in mind that the engine averaged  $2\frac{42}{100}$  per cent. more cars while using the pump than while using the injector.

In these experiments two empty cars are rated as being equal to one loaded car in computing the average cars hauled. The regulation load on the Illinois Central Railroad is ten tons for a freight car, and the average weight of empty freight cars is 18,000 pounds.

On the section of road where these experiments were tried the track is in excellent condition; the heaviest grade is about thirty feet to the mile, and the curves are few in number and long in radius.

The variations in steam pressure were from 90 pounds to 120 pounds while using the pump, and from 100 to 120 pounds while using the injector. The variations were fewer in number with the injector than with the pump, and the engine made steam more freely while using the injector. The average boiler pressure was 113 pounds per square inch during the experiments, and was obtained by noting the pressure indicated by the steam gauge, at regular intervals of time, while the engine was working.

On October 7th, under telegraph orders, the engine hauled a train of twenty loaded and two empty cars from Gilman to Kankakee, a distance of twenty-five miles, in forty-seven minutes. The injector was worked to its full capacity during this run, and supplied the boiler with water. The amount injected in the forty-seven minutes was  $1,005\frac{22}{100}$  gallons, being an average of  $21\frac{38}{100}$  gallons per minute. The boiler had three gauges of water on leaving Gilman and the same amount on arriving at Kankakee, and close observation of the water gauge failed to detect a variation in the level of the water except that due to the motion of the engine. The average pressure in the boiler during this run was 114 pounds per square inch. This proved that the injector was large enough to supply the boiler with water when the engine was worked to her full capacity. At other times, when standing at stations, it was found necessary to shut off the injector to prevent flooding the boiler, as the injector did not at

that time have the regulator attachment for returning the surplus feed water to the tank. This attachment was afterwards put on, and experimented with, and will be referred to hereafter in this report.

For further information on this branch of the subject you are respectfully referred to the two following tables, one giving in detail the eight trips made while using the injector exclusively, and the other giving similar information in relation the eight trips during which the water was injected by the pump.

# EXPERIMENTS WITH THE INJECTOR-ILLINOIS CENTRAL RAILROAD.

Direction .....	Date of trip.....	Blowing off time while standing.....	Total time on the road.....	Standing time.....	Switching time. ....	Running time.....	Average speed in miles per hour .....	Total miles run.....	Average cars hauled.....	Pounds of coal.....	Pounds of water.....	Evaporation per lb. of coal.	Miles run per ton of coal....	Pounds of water used per mile .....	Average steam pressure.....	Weather .....	REMARKS.
South .....	Oct. 2, 3.....	1.35	11.25	3.55	.25	7.05	18.15	128	23.27	8015	45945	5.73	31.94	358	112	Fair ...	{ Strong side wind, train ran easy, en- gine steamed freely.
North .....	" 4, 5.....	1.10	11.20	2.50	.....	8.30	15.42	128	27.42	8591	50537	5.26	26.72	394	111	"	{ Light back wind, engine steamed freely.
South .....	" 5, 6.....	1.40	12.00	3.05	1.10	7.45	17.18	128	23.81	7620	44202	5.80	33.59	345	112	Rainy..	Strong " " "
North .....	" 6, 7.....	1.45	12.25	3.55	1.45	6.45	19.84	128	20.62	8653	45086	5.21	29.62	352	113	"	{ Light back wind, ran from Gilman to Kankakee in forty-seven minutes.
South .....	" 8, 9.....	1.33	12.00	3.25	.15	8.17	15.66	128	21.37	7890	43179	5.47	32.48	337	114	Clear...	Strong back wind, engine steam'd freely.
North .....	" 9, 10.....	1.45	13.15	3.55	.50	8.30	15.42	128	24.63	10418	53055	5.09	24.61	414	115	Rainy..	{ Light back wind, train pulled hard, engine steamed freely.
South .....	" 12.....	4.05	17.30	6.45	4.15	6.30	20.31	128	17.27	10300	55498	5.38	24.85	433	114	Clear...	{ Light back wind, engine steamed freely.
North .....	" 13.....	1.35	13.00	3.25	1.20	8.15	15.70	128	20.09	7405	37108	5.01	34.43	289	114	"	{ Light back wind, train ran easy, en- gine steamed freely.
Total.....	.....	15.08	102.55	31.18	10.00	61.37	.....	1024	.....	69892	374610	.....	.....	.....	.....	.....	.....
Average...	.....	1.53	12.52	3.55	1.15	7.42	17.21	.....	22.31	8736	46826	5.36	29.78	365	113	.....	.....

Pounds of coal per mile, 68.25

	REMARKS.					
	(Strong side wind, train ran easy, engine did not steam freely.) { Light side wind, train pulled hard, engine did not steam freely. Strong back wind, { Train ran easy, engine did not steam as well with pump as with injector. Light " " { Light back wind, { Train ran easy, engine steamed well but not as freely as with the injector. " " " Strong " " " " "					
Weather .....	113	Fair....				
Average steam pressure.....	118	"				
Pounds of water used per mile.....	387	"				
Miles run per ton of coal....	47029	5.15 28.07	387			
Evaporation per lb. of coal.	53891	4.85 23.25	421			
Pounds of water.....	52924	4.97 24.02	413			
Pounds of coal.....	46913	5.19 28.35	866			
Average cars hauled.....	40364	5.36 34.04	315			
Total miles run.....	45410	5.28 29.78	954			
Average speed in miles per hour .....	50157	4.96 25.32	391			
Running time.....	54427	5.37 25.26	425			
Switching time.....	391106					
Standing time.....	48888	5.14 27.26	382			
Total time on road.....						
Blowing off time while standing.....						
Date of trip.....	Oct. 14, 15... " 16, 16... " 18... " 19... " 20, 21... " 21, 22... " 23... " 25.....					
Direction .....	South..... North..... South..... North..... South..... North..... South..... North..... Total..... Average..					

**Pounds of coal per mile, 74.44**

The next series of experiments were made with a view of determining the temperature of water injected into the boiler with different pressures of steam, and also to afford an opportunity for noting the length of time required to get the injector properly at work.

A cock was inserted in the feed pipe, between the injector and the check valve on the boiler, and water was drawn through this cock into a vessel in which were placed two thermometers for the purpose of measuring the temperatures. In nearly all cases two trials were had each time the injector was put in operation.

Commencing with 130 pounds of steam, as indicated by the gauge, which was tested just before commencing the experiments, the tests were made until the pressure in the boiler was reduced to 10 pounds per square inch.

The temperature varied from 170 degrees with 130 pounds pressure, to 96 degrees with 30 pounds and 10 pounds pressure, as will be seen from the following table :

*Experiments made with Injector to determine the Temperature of the Feed Water at different Pressures of Steam in the Boiler.*

Pressure of Steam.	FIRST EXPERIMENT.		SECOND EXPERIMENT.	
	Starting Time.	Temperature.	Starting Time.	Temperature.
130 pounds,	.....	139 degrees,	5 seconds,	170 degrees.
120 "	4 seconds,	130 "		137 "
115 "	40 "	129 "		126 "
100 "	6 "	123 "		122 "
90 "	5 "	129 "		121 "
80 "	7 "	112 "	5 "	
70 "	4 "	132 "		
68 "	5 "	120 "		
60 "	17 "	121 "		110 "
50 "	10 "	115 "	5 "	104 "
40 "	17 "	110 "	10 "	106 "
30 "	10 "	96 "		103 "
20 "	.....	105 "		108 "
15 "	.....	100 "		100 "
19 "	.....	114 "		96 "

With a pressure of 130 pounds four tests of temperature were



made, viz.: 139, 170, 150, and 140 degrees, showing that by changing the proportion of steam used, to water injected, a variation of 21 degrees could be obtained in the temperature of the feed water.

When the pressure in the boiler was reduced to 10 pounds per square inch the injector was started and allowed to run, the boiler pressure decreasing meanwhile, until at 7 pounds the stream broke and the injector was shut off and started again. At 5 pounds pressure the stream broke again and the injector was shut off and started, and continued working until the pressure fell to four pounds, when the injector failed again and the experiments were discontinued.

This demonstrated the fact that an injector will work at low steam pressures, although with less force and capacity than with the higher pressures of steam.

The time necessary for starting the injector varied from four to forty seconds in fifteen observations; in only one case did it exceed seventeen seconds, and the delay of forty seconds was no doubt caused by the injector becoming overheated by steam passing through it.

The third series of experiments were made to ascertain the greatest and the least quantity of water which a No. 6 Injector would force into a boiler in a given length of time. These and also the tests of temperature were made while the engine was standing in the engine house. Under these circumstances the greatest amount of water injected was  $18\frac{1}{10}$  gallons per minute, the pressure of steam being 110 pounds and the injector working to its full capacity, being about three gallons less per minute than was injected during the run from Gilman to Kankakee, on October 7th, with an average pressure of 114 pounds per square inch in the boiler.

The smallest quantity of water injected with 110 pounds of steam was  $10\frac{1}{10}$  gallons per minute, and with 100 pounds pressure  $8\frac{7}{10}$  per minute, which shows that an injector can only be graduated from full to about half feed.

The following tables exhibit this series of experiments :

*Experiments to determine the Maximum Quantity of Water per Minute forced into the Boiler without the Regulator Attachment for carrying the surplus Water back to Tank.*

No. of TRIALS.	Total time consumed.	Amount of water injected in gallons.....	Amount of water injected per minute in gallons.....	Pressure of steam at time of starting.....	Pressure of steam at close.....
First Trial.....	6 minutes, 20 seconds,	103.10	16.28	100 pounds,	90 pounds.
Second " .....	5 " 40 "	103.10	18.21	110 "	90 "

*Experiments to determine the Minimum Quantity of Water per Minute forced into the Boiler without the Regulator Attachment for carrying the surplus Water back to Tank.*

No. of TRIALS.	Total time consumed.	Amount of water injected in gallons.....	Amount of water injected per minute in gallons.....	Pressure of steam at time of starting.....	Pressure of steam at close.....
First Trial.....	9 minutes, 10 seconds,	103.10	11.25	110 pounds,	90 pounds.
Second Trial.....	11 " 45 "	103.10	8.77	100 "	85 "
Third Trial.....	10 " 10 "	103.10	10.14	110 "	95 "

The foregoing demonstrated the fact that an injector, as ordinarily constructed and large enough to supply a heavy freight engine, worked to her full capacity, could not be graduated to a sufficiently fine feed when the engine was employed in very light service. A regulator for returning the surplus feed water to the tank was therefore obtained and attached to the injector used in these experiments. The object of this device is to diminish the quantity of water forced into the boiler, by returning the surplus water to the tank, from the

injector, through an independent pipe having a cock which can be opened wholly, or partially, at pleasure.

It is evident that the effect of returning the heated feed water to the tank must be to heat the water in the tank, and perhaps interfere with the working of the injector and also blister the paint on the tank. To determine these questions the following experiments were made:

With a steam pressure of 120 pounds in the boiler the injector was started and the regulator attachment was opened, so as to return nearly all the feed water to the tank instead of forcing it into the boiler. The injector continued working for two hours and thirty-five minutes, during which time only  $257\frac{7}{100}$  gallons were injected into the boiler, being an average of  $1\frac{4}{100}$  gallons per minute. The injector was worked the whole time to its full capacity. At the expiration of the two hours and thirty-five minutes the injector stopped working and the water in the tank was heated to the following temperatures:

Water drawn from front end of tank, on left side, the injector being on opposite side, 124 degrees.

Water at manhole for filling tank 130 degrees.

Water drawn from the hose through which injector was supplied 120 degrees.

The steam pressure was maintained at 120 pounds during the two hours and thirty-five minutes.

After testing the temperature of the water in the tank, as described, the injector was started again and the temperature of the feed water, after passing through the injector, was measured and found to be 180 degrees; the boiler pressure had meantime decreased to 105 pounds per square inch, and the temperature of the water in the tank was from 120 to 130 degrees as previously stated. The injector was allowed to work until the water in the tank was heated to 140 degrees at the manhole, when it was shut off as the varnish began to soften a little.

Efforts were then made to start the injector again, but proved unsuccessful for twenty minutes. At the end of that time it was started and worked, although the temperature of the water in the tank was found to be as follows:

Water drawn from front end of tank, left side, 132 degrees.

Water at manhole of tank 138 degrees.

Water drawn from the hose through which the injector was supplied 130 degrees.

The injector was shut off while these temperatures were obtained, after which it was again started, but the stream broke in three or four minutes, no doubt because the water in the tank was too hot. The pressure in the boiler was 110 pounds per square inch.

The temperature of the air in the building where the experiments were made, ranged from 55 to 60 degrees.

This ended the experiments with the injector.

Your Committee do not understand that it is within their province to offer any opinions as to the relative values of different kinds of injectors. They desire, however, to call your attention to a few conclusions based on these experiments.

1. A good injector properly attached, is as reliable as a pump for feeding a locomotive boiler, provided the water in the tank is not heated to more than 110 degrees Fahrenheit.

2. A small saving in fuel is effected by using an injector; the boiler pressure is steadier, and the boiler is subjected to fewer changes in temperature.

3. A pump will feed only when the engine is moving, but an injector will feed the boiler when the engine is in motion or at rest.

Your Committee also desire to state that, in their opinion, efforts should be made to construct an injector which can be regulated from full feed to one-tenth full feed, without the regulator attachment herein described; it should also work well at an elevation of not less than four feet above the level of the water in the tank, and should be placed in a convenient position on the engine.

It is possible that in a warm climate, or under a hot sun, the return of the surplus feed water to the tank may heat the water in the tank to 120 or 130 degrees in much less time than two hours and thirty-five minutes, which was the time required when the atmosphere was from 55 to 60 degrees. On this point your Committee can not give you any information founded on fact. This is the only objection your Committee can see to the plan of reducing the amount of water injected into the boiler by returning the surplus feed water to the tank.

Your Committee desire to return their thanks to Mr. S. J. Hayes, Superintendent of Machinery of the Illinois Central Railroad Com-

pany, for his kindness in affording the Chairman of your Committee every possible facility for conducting these experiments.

As one of the members of this Committee has not been heard from, although the Chairman has written to him three times, his name is not appended to this report.

Respectfully,

E. T. JEFFERY, *Illinois Central,*  
G. W. CUSHING, *Missouri, Kan. & Texas,* } *Committee.*

On motion, the report was received.

THE PRESIDENT—Unless there is some objection the subject is open for discussion.

Mr. ROBINSON, of Canada—If any member of that Committee is present, I would like to ask, in what position of the boiler they recommend the water should be delivered? There should be a reason for certain differences that exist in the report. The injectors mostly deliver the water into the leg of the fire box. There is, no doubt, a reason for this. In the report they consider that the injection water is always warm, whereas the pumps deliver cold water, and it is delivered more to the front, and now it is a matter for us to consider whether their reason shall be a guide for us in this country.

Mr. HAYES, *Illinois Central Railroad*—As none of the Committee are present, and I am pretty familiar with all the experiments, as they were made with an engine on our road, I will answer Mr. Robinson. The feed water was thrown in very near the usual place for the check valve in our engines. My own opinion of the matter is that with the water thrown warm into the boiler it would make no difference whether put in the leg or center part of the boiler. In the former way of working the cold water pump, it was customary to put it in front of the boiler and have the circulation pass back gradually. We found that by putting the check valve in the side of the furnace it was subject to expansion and contraction, and caused the flues to leak. That would not be the case with an injector. Makers of injectors have recommended the valve to be put in the same place. I believe that answers the question.

Mr. ROBINSON, of Canada—I would ask Mr. Hayes, if in placing the pipe in the fire box, whether it is not more protected from cold, so there is no intermediate contact with cold currents? That is one of the reasons given for adopting the plan of putting it in front of the fire box.

Mr. WOODCOCK, *Central Railroad of New Jersey*—There would be less liability of freezing up if the check were placed nearer the injector and the back part of the boiler. In our very cold country we sometimes have those pipes freeze up, and it is necessary to use a jet of steam to keep them open. I think it would be better to put it at the back of the boiler, particularly in cold climates.

Mr. FRY, Philadelphia & Erie Railroad—It may be interesting to know that there are several railroads in this country that have tried the experiment of placing the check for the injector in the fire box. I remember seeing injectors placed in engines on the Northern Central and Erie in that way, and I remember of making an inquiry at the time as to whether bad results had attended, and in neither instance did I hear any objection raised on account of leakage in flues.

Mr. WILDER, Erie Railway—Many of our engines had injectors, and for convenience valves were placed on the back end of the boiler. We never had any bad results from it, but they were never used to supply the engines while in service, and oftentimes were not used once a month. They were never used continuously.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—Many years ago it was the custom of builders to place check valves near the fire box. I remember in several instances of fire boxes where the checks were on the side in which we always found a large deposit of scale in the neighborhood of the checks, and I presume that would be the case if delivered by an injector, as we have found it in the cylinder part of the boiler, in the vicinity of the check and for several feet from it, where it was not found in other parts. When water first enters the boiler and begins to heat up, mineral substances in it will be precipitated. Very soon afterwards large quantities will settle and form more scale on the surfaces than at other points, and if we deliver the water at the back part of the boiler I think this would be the result to a certain extent. In using bad water in boilers it would necessarily be an objection. It would be important to know on some of our roads—where we use very bad water—whether the lime and other impurities in the water would not collect on the inner surface of the receiving nozzle of the injector, and would form a scale that would interfere with its working. I remember a number of years ago where we had attached five or six of them to different engines in use, and in using the water that had more or less lime, we had a great deal of trouble on that account. After two months we would find a thin scale on the inside of the nozzles, and a scale of the same character on the surface of the fire box, and we were obliged to take these nozzles out and polish them again; then it would work as well as ever for a month or two; but as we had to use that water almost entirely, and it became troublesome and expensive to be cleaning these nozzles, the use of injectors for running engines was discontinued, and they were used afterward only for switch engines; whether that has been the experience of other members I do not know. That has been mine. Where the water is pure of course that objection would not occur.

Mr. WOODCOCK, Central Railroad of New Jersey—I think what Mr. Wells has said in reference to scale accumulating on the side sheets of the furnace is in a measure true. I remember some years ago one of the locomotive works delivered four engines—freight engines—about the time injectors

first came into use, they were of novel pattern and complicated; these injectors were placed on the side of the furnace; they were run a year I believe, and we thought some ill-effect was coming from it, and after consultation it was thought best to change them, and we changed the checks on the four engines, and put them in the cylinder part of the boiler. I do not recollect of putting them in since except on shifting engines. I think the check should be placed in the middle of the boiler, or nearly so, with a straight pipe connection. Some checks are now arranged in this way, and the water is delivered in a place where no serious results will arise from it. I have had some experience of placing checks in the boiler in front, and I found that in a short time the sheet would bulge and eventually crack; the only experience is on those four engines, and I believe that in time it would have resulted in the same way.

Mr. LEWIS, Northern Central Railway—In view of the difficulty spoken of by Mr. Wells, of the formation of scale at the entrance of the feed water to the boiler, I think it would be well to place the check in some place in the boiler, either in the leg or front of the boiler if it be preferable, where it would be accessible from the manhole plate. So far as injecting cold water near the fire box, I have never seen any that did not have a collection of scale which prevented the water from coming in contact with the sheet. I think the location should be where it can be removed, when the engine is washed out, through the manhole plate.

Mr. HUDSON, Rogers Locomotive Works—I have no doubt that the formation of scale is an objection to introducing water into the fire box; there are other objections, the temperature is much less than the temperature of the fire box, and the temperature of the water, though higher than as if coming from a pump is still less than it is in the furnace. The true place to introduce the water is near the forward end of the cylinder part, very much the same as with a pump, because the heat passing through the tubes there is very little in comparison with other parts of it, and if we introduce water at that point, while still lower than steam pressure, it is capable of giving some heat from the heat passing through the tubes. It is well known that if you take six inches near the furnace, you will generate with that six inches as much steam as with three or four feet further away, therefore I have no doubt at all that the place to introduce water is near the forward end of the boiler.

Mr. FORNEY, Railroad Gazette—I would like to ask Mr. Hudson on what grounds his statement is based, that as much steam is produced in the first six inches as in the next few feet. I have heard the statement made several times, but never knew any authority for it.

Mr. HUDSON, Rogers Locomotive Works—I think Mr. Forney will find it in a little pamphlet published by Charles W. Williams, who tried the experiment of putting partitions in the boilers; I am speaking at random as

to the precise amount, but there is a very great difference. I will hunt up the pamphlet for him and furnish him the information.

Mr. FORNEY, Railroad Gazette—I am familiar with the pamphlet, and once bought it, and in these experiments that were made there was no forced blast. I imagine the result would be very different with a forced blast. I was in pursuit of that little fact and tried to find it, but failed to do so.

Mr. HUDSON, Rogers Locomotive Works—While we may differ as to the relative importance of a few feet of the front or back end, Mr. Forney will not dispute the fact that there is a very great difference as to the temperature and the amount of heat even with a forced blast.

Mr. FORNEY, Railroad Gazette—I do not doubt the statement Mr. Hudson makes is strictly correct, but the fact that the first few inches produces more steam than any other portion, has been used as an argument for shortening the tubes, and I think a false conclusion has been formed, and I am inclined to doubt whether so large a proportion is produced at the front end. I think in a locomotive where an immense amount of steam is produced that the length of the tube is a very important matter. I think, with Mr. Hudson, for the same reasons that he states, that the temperature at the front end is comparatively low and will not impart any heat to hot water but will impart it to cold water, and therefore the economy of introducing cold water.

Mr. LEWIS, Northern Central Railroad—My statement in regard to the injury to the boiler, as resulting from scale, was based upon a pump attachment to a stationary boiler of mine. My stationary feed pump was a Cope & Maxwell, and the check pipe was one and a half inches; when the engine was run to its full capacity it took nearly half the time to supply the boiler. I have never seen any injurious effects from injecting near the leg of the boiler. It is my opinion the sheets were not affected by the difference of temperature so much as by the accumulation of deposits.

Mr. FRY, Philadelphia & Erie Railroad—If the experience of Mr. Lewis is correct, that the temperature of the water does not damage the stays and plates, I should like to know whether it is any advantage to put the water in at the coldest end. The tendency is to get the fire-box plates overheated. The steam gets very much hotter than the fire box in the front end of the boiler; the circulation is not regular, and possibly we might effect an economy in the life of our fire boxes by introducing cold water where the heat would be greatest; we should keep our plates clear by introducing the feed water there; it seems that we assume that it is best to introduce the water at the coldest part of the boiler, but I would like to know whether there is any good reason for it.

Mr. HUDSON, Rogers Locomotive Works—I apprehend that it is not entirely a matter of assumption. I can recollect some locomotives built in 1838, that were on the Auburn & Syracuse Railroad about its commencement, in which water was introduced in the leg of the furnace under the cylinder part, under its sides from the pumps; of course there were no injectors at



that time, and the difficulty experienced was this: That while using the pumps it was almost impossible to keep the tubes from leaking. The engines would be tight if a very small quantity of water was introduced, but if put on full the tubes commenced to leak, and the difficulty was so great that the checks were removed and put on the forward end of the boiler and no further difficulty was experienced from that source. There is a practical evidence of the benefit of changing. Now if the benefit of introducing the water into the leg of the boiler should have been to carry off the heat it carried it off too fast, it reduced it too much and caused the tubes to leak. There is no doubt that it is desirable to introduce some better mode of circulation, but I do not think it should be done in that manner.

Mr. FRY, Philadelphia & Erie Railroad—We are discussing the application of the injector to the locomotive; I have something of the experience of Mr. Lewis, that the hot water that the injector introduces does not produce the bad effects of the cold water from the pumps. Supposing that the experience of Mr. Lewis is correct, that we can not introduce hot water from the injector, is it therefore better to carry the water through the valve of the pumps or put it into the leg of the fire box? If I understood Mr. Hudson's first proposition it was that the bottom of the boiler was the best place to introduce it.

Mr. HUDSON, Rogers Locomotive Works—That is so.

Mr. FORNEY, Railroad Gazette—One thing in which I agree with Mr. Hudson is that if you introduce the cold water at the front end of the boiler the front end of the tubes is the coldest. If you bring hot water in contact with the cold tubes the heat in the tubes will not be communicated to it; but if the cold water is brought in contact with the cold end of the tubes the heat in them will be communicated to it. I recommended a few years ago an arrangement of three series of tubes, and the boilers so constructed were found to be exceedingly economical. The cold water being at the lower part of the boiler came in contact with the tubes at their lowest temperature, and the heat they contained was communicated and so much was saved.

Mr. ROBINSON, of Canada—As touching Mr. Lewis' remarks about the position of delivery, I might say that when in the old country I was familiar with one or two hundred engines that had no pumps, but had two injectors in the back of the fire box, on the right and on the left. The delivery pipe was about two and a quarter inches in diameter; they went down to each side of the fire box and turned up about a foot; there is a plate placed between these two delivery holes and also the usual washout plugs at the corners—these are for safety—the space is perfectly clear where delivered. We generally know what kind of water they use on that road, as compared with what is used here, and what is successful there might not be successful here. Several engines run for twelve months and no difficulty was found in the aperture filling up. This brings me to Mr. Wells' remarks about the holes filling up. That does take place with the pump; but the injector throw-

ing in hot water causes the sediment to diffuse in such a manner that precipitation takes place and adheres to the first thing it comes in contact with. The orifice of the check fills up until it is hardly large enough for a pea to pass through, even though it were two inches in diameter a few months before; that covers Mr. Lewis' remarks, and shows there is an experience in that mode of placing the injector. The leg of the fire box is the lowest place of the boiler, and I am not prepared to believe that the back leg of the fire box, up to a couple of feet high, is any hotter than the side of the barrel of the boiler, because there you throw the water directly upon hot tubes, and your throwing this cold water on tubes tolerably hot is not like throwing water on the plate, and the fire being drawn from that plate and not to it. I would remark that in the boilers where these injectors were used the fire boxes were made of copper; if made of steel or iron it would have been more valuable to us in our discussion. I am not able to say now that this is absolutely correct, but it is well worth thinking about, and I would suggest that that Committee be continued, adding to its heading: "The Best Place for Placing the Injector."

Mr. WILDER, Erie Railway—I understand that on the Lake Shore Railroad they are placing large sized injectors on some of their engines. Mr Sedgley is here and can tell us about it.

Mr. SEDGLEY, Lake Shore Railroad—In answer to Mr. Wilder's question, I would state that we have applied to several of our heavy engines injectors with the design or desire to find some better method of supplying our engines with water than the pump; although the experiment has been of recent date, and I can not give you the figures, yet we find them very efficient, so much so that our men who run them would not be willing to have the pumps replaced. I hope we may make some statement before next year that will be of some service to the Convention. We are running one engine with very excellent success, and it is the impression of the men that we are saving fuel. There are several advantages that we get from the injector that we do not have from the pump. We all know that with a heavy train with a pump we cease to supply the boiler when the engine stops, but with the injector the supply is going on very much to the advantage of the boiler.

Mr. CLARKE, Lehigh Valley Railroad—On our road the water is very bad, it has a great deal of carbonate of lime and a great deal of precipitate. The last improved engines are fitted with two pumps. I used a small auxiliary injector placed beneath the fire door, in back leg of the fire box, and I inject water there and find no trouble from the collection of scale. I put a handhole in such a position that whenever the engine is washed out it can be cleaned. I think there is no trouble with the injectors.

Mr. EDDY, Boston & Albany Railroad—I did not intend to consume any time in this matter or say anything, but it will be interesting, perhaps, for the Convention to know the little experience we have had on our road. Some twenty-five years ago I worked the pump by an eccentric on the back

sheet and found it convenient to put the water in the back sheet near the bottom; I found very great trouble from leaking tubes and breaking of stay bolts. Though it was very much to our advantage to put in the water at that point I shifted them to the barrel of the boiler at the front end, and found a very great advantage in that respect. I do not believe that under any circumstances you can put the water into the furnace part of the boiler and get as good results as in front. If by an injector you heat it as hot as the water in the boiler you are all right, but if at a lower temperature the result will be correspondingly bad.

Mr. CLARKE, Lehigh Valley Railroad—These injectors are only auxiliary injectors. From my experience I believe there is no trouble by injecting the water there. We have engines with injectors in the furnace that have been used for four or five years, and the sheets are not injured in the least.

Mr. HUDSON, Rogers Locomotive Works—I may state a fact in corroboration in regard to what Mr. Wells says about scale forming on the inside and preventing its working for some time. I know several roads we have supplied with injectors, and after a few months they became choked up with scale. Something depends upon the quality of the water. There is no doubt of the incidental advantages of the injectors over pumps, as in regard to supplying boilers with water at stations when standing, but they are then supplying the boiler in such cases and supplying it regularly. I doubt very much whether that is any advantage over pumps. The difficulty with many locomotive engineers is that they work the pumps spasmodically. They pump all or none. Every good engineer knows that is a bad practice; they ought to introduce the water as they use it. I apprehend if it were done with a pump as with a No. 6 Injector the difference would not, perhaps, be so great.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—I fear from Mr. Robinson's remarks that he has misunderstood me in reference to closing up the mouth of the check where it enters the boiler. He speaks of my allusion to the formation of scale; I did not allude to that at all; I never had any difficulty with the injector that I have had with pumps; I did not find that difficulty with the injector, I only referred to the deposit of scale on sheets in the immediate vicinity of where the water entered the boiler.

Mr. FRX, Philadelphia & Erie Railroad—It would be well to bear in mind that the introduction of the injector raises one or two points upon which we need more information; first, whether it is possible to introduce water in the fire box; it would be interesting to know whether the temperature of the gases escaping into the fire box is sufficiently low to make the argument of Mr. Forney of any moment, that the heat of the tubes is so slight at the front end that it can not impart any more heat; also the temperature of the water at different parts of the boiler and the effect of the introduction of water in the fire box; ascertaining what the temperature at the boiler and

legs of the fire box is; also whether introducing water at the legs lowers the temperature. Some very interesting information is needed by the Convention as to the introduction of the injector, the use of which enables us to do what we attempted to do in former times and failed.

Mr. HAYES, Illinois Central Railroad—Some twenty years ago I made some experiments with the thermometer in the smoke arch of a Baltimore & Ohio locomotive working at full power. After trying for several days I broke the thermometer, and I found the temperature varied from three hundred to eight hundred degrees. After breaking the thermometer I conducted the experiments with different metals that would fuse at certain temperatures; I found that the experiments with metals resulted about the same as with the thermometer. We all know that the temperature of steam at about one hundred and thirty pounds pressure is about seven hundred and forty degrees; if we can utilize any of that there is a saving; the heat in these experiments would vary from one hundred and thirty to one hundred and eighty degrees, all imparted to the water thrown into the boiler. As Mr. Hudson says, if we can get it in at the front end, of course it does not subject the flues to that contraction and expansion, and of course the injector would not injure the flues so much as at the front end of the fire box, and I agree with him that the better place would be in favor of some part of the front of the boiler.

Mr. WILDER, Erie Railway—We seem to have overlooked the question, whether to do away with pumps and introduce injectors. The whole discussion has been about plates and where to put the check; we have got to put the water into the boiler some way; let us see whether the injectors are better, and discuss the question on that side a while. I will say in this connection we have one engine which has two injectors and no pumps. It has been in service two years and in the meantime the results from the injector have been very good for short runs, for when the engine stops the injectors keep to work, and for that reason we have no difficulty about the engine blowing off, and I think from the results obtained in that direction that the injectors are better than the pumps.

On motion of Mr. Robinson the discussion of the subject was closed.

Mr. CHAPMAN, Cleveland & Pittsburgh Railroad—I move that a committee of three be appointed to prepare subjects for discussion next year.

The motion was carried.

THE PRESIDENT—I will appoint as that Committee Messrs. Woodcock, Forney, and Peter Clarke.

Mr. FORNEY, Railroad Gazette—I would ask to be excused from serving on that committee, as I have served for several years and have run out of subjects.

THE PRESIDENT—If the only objection is because you have been on for several years, it is reason for putting you on again. If any member has any subject that he wishes brought before the Convention he will

present it to the committee. It has also been customary to appoint a Committee on Correspondence. There are a great many letters that require answers and some require immediate action, and there should be a committee to investigate them. I will appoint Messrs. Wells, Sedgley, and Wilder. There should also be an Assessment Committee and the amount of assessment decided upon. I will appoint as such committee Messrs. Lauder, McAllister, and Warren. I would state to those members who have come into the hall since the resolution, that the Convention has resolved to have two sessions a day, from 9 to 1 and from 2 to 5 o'clock, until our business is finished. As it is now 1 o'clock we will adjourn until 2 o'clock.

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### AFTERNOON SESSION.

**THE PRESIDENT**—The next business in order is to hear the report of the Committee on "The Best Material, Form, and Proportion of Locomotive Boilers and Fire Boxes." The Committee are Messrs. Wells, Peddle, Hayes Cummings, and Young. The report is in the hands of the Secretary.

#### **Report of Committee on the Best Materials, Form, and Proportions of Locomotive Boilers and Fire Boxes.**

*To the American Railway Master Mechanics' Association:*

**GENTLEMEN**—At your last Annual Meeting the undersigned were appointed a Committee on the subject of "The Best Materials, Form, and Proportion of Locomotive Boilers and Fire Boxes," with the request that we should report to you, as the result of our investigations, such facts as might seem to us worthy of your attention.

Your Committee issued a circular in which such questions were asked as appeared to us most likely to elicit the desired information on the several subjects assigned to us for investigation; but as these subjects covered much ground the questions asked were necessarily numerous, and some of them of considerable length, we have concluded to omit them from our report, and in their stead to give only the substance of them, in their proper order and place. Before considering these questions, however, we deem it proper, in justice to ourselves, to state that out of about two hundred members belonging to our Association, who are at this time in charge of the Locomotive Department on the different roads in this country, but nineteen of

that number have made any reply to the circular of your Committee; therefore, instead of being able to present to you conclusions formed from the experience and observation of a very large proportion of those in charge of the locomotives in use in the United States, we are obliged to base them mainly on the facts presented by the nineteen referred to added to that of our own.

#### THE BEST MATERIAL FOR THE SHELL OF THE BOILER.

Answers to this question were received from those having an aggregate of 1,690 coal-burning locomotives under their supervision, 276 of which are reported as having steel boilers entire. Those representing 602 locomotives express their preference for good iron, while those representing 1,088 consider steel to be the best material, all things considered.

We find that on roads where steel has been the most largely used, such as the Lake Shore & Michigan Southern, Pittsburgh, Fort Wayne & Chicago, and the Central Railroad of New Jersey, that the preference by those in charge is decidedly in its favor.

The question between the use of iron and steel for the shell of the boiler, under our limited experience in the use of the latter metal, can not at present be very satisfactorily determined. As a Committee, we would call attention to the fact of the superior tensile strength of steel over iron, less liability to injury, or to prove defective from flanging and other manipulations, and to the fact that the cost of constructing a steel boiler, aside from the difference in the first cost of the plates, is no greater than that of an iron boiler, and that that difference of first cost would not exceed from one to two hundred dollars in the total cost of the boiler.

If steel possesses greater strength than iron, and is equally or more pliable, then a boiler made of it should be stronger and safer than one made of iron, other things being equal; and where that is the case, the matter of one or two hundred dollars in the first cost is scarcely worth considering. In the use of steel for the shell of a boiler we would recommend that the same thickness of sheets be used that has heretofore been adopted in the use of iron.

It is a matter of vital importance that the boiler should always have abundant strength for the pressure carried, and in its construction and maintenance this matter should receive pre-eminent attention.

## THE BEST MATERIAL FOR FIRE BOXES.

To this question we have received the same answer from all, with the exception of Mr. Graham of the Delaware, Lackawanna & Western Railroad. All the others give steel the preference over any other metal. Mr. Graham states that his experience has been with corrugated iron mostly; and that it has been quite satisfactory, and on that account he gives it the preference. He states also that he is now using a steel fire box with one of the side sheets corrugated, while the other is plain, and that he intends doing the same with an iron fire box, in order to test the relative merits of corrugation, and also that of steel and iron, in the use of anthracite coal which is exclusively used on that road.

As steel of a low grade has so firmly established itself in favor, and is almost universally used for the fire-box sheets of coal-burning locomotives, we do not consider it necessary to present the relative merits of steel, iron, and copper, but we may safely conclude that steel is the best. Steel of a low grade seems to meet all the requirements, if we except its tendency to crack in the case of the large side sheets of the fire box. This tendency is not confined to steel, but reports show that iron has the same tendency in an equal if not greater degree, besides its liability to blister from imperfect welding in the process of manufacture, or, in other words, from not being perfectly homogeneous. The tendency to crack is not confined to any one kind of steel, nor to one manufacture, but from the reports we learn that sheets have ruptured which have been made by all the different manufacturers whose steel is in general use, both that made by what is known as the "Siemens-Martin," or open-hearth process, and the "crucible."

With the above facts before them, your Committee deemed it important to direct their inquiries mainly to the causes which result in these mysterious ruptures that sometimes occur in the larger sheets of a fire box without any apparent cause at the time. In our investigation we have had reported to us 1,690 coal-burning locomotives; of this number 232 having steel fire boxes burned anthracite coal, and 1,040 burned bituminous coal; 388 had iron fire boxes, and 30 copper.

Those engines in which anthracite coal was burned had mostly the long and shallow fire box, from 7 to 9 feet in length, and the sheets

reported ruptured within the past two years was only one; yet it is proper to state that at least in one case, that of the Central Railroad of New Jersey, the number of ruptured sheets is not given; Mr. Woodcock in his report to us refers to such sheets, but gives no data as to their number.

The 1,040 engines with steel fire boxes in which bituminous coal was burned have comparatively deep fire boxes, the side sheets of which are from 5 feet to 5 feet 6 inches long, and 4 feet 6 inches to 5 feet from crown sheet to the grate. The number of sheets ruptured in these fire boxes within the past two years is reported to be 125. Of this number 121 were side sheets, 3 door or back sheets, and 1 tube sheet.

We also learn that in 118 of these side sheets, rupture occurred near the vertical center line, and in nearly every case the crack was vertical. A few however took a more or less diagonal direction a part of the distance. The *beginning* of all these cracks was, in every case reported, at a stay bolt, hollow stay, or rivet, and from 6 to 12 inches above the grate. In three cases reported, side sheets have ruptured near the forward lower corner, the crack starting about six inches above the grate at a stay bolt, and extending upward and forward at an angle of about 30 degrees from a perpendicular. Only 3 back sheets are reported as having ruptured; in 2 of them the crack starting from rivets at the fire door and extending diagonally downward some 12 or 14 inches. No report is made of any crown sheets having ruptured, and but 1 tube sheet, which is stated to have cracked from some obstruction occurring in the water space below the tubes.

We find that rupture in the cases reported occurred under various and nearly all circumstances, except when the boiler was under steam with fire on the grate.

In some cases it occurred while the boiler was being washed out, in others while filling with cold water; sometimes when standing empty, at others when cooling down and nearly cold; sometimes after standing a day or two, or while stay bolts were being calked, or other work producing a jar or vibration of the sheet; and in a few cases the rupture took place just after a fire was started in firing up and before steam was raised in the boiler. It seemed to us that the questions demanding a solution then are: Why is it that the side



sheets only of the comparatively deep and large fire boxes are ruptured under the circumstances named, and that the proportion of rupture in those that are long and shallow is so much less than in the deep and large boxes? Why is it that when rupture takes place the crack is almost invariably vertical, and not far from the vertical center line, and at a point where the heat is usually the greatest?

Why is it that if some side sheets rupture, others subjected to precisely the same treatment, under the same circumstances, do not? And is there a remedy that will largely, if not entirely, prevent the evil referred to?

With the view of being able to suggest a remedy your Committee desired first to ascertain the cause, and in their circular asked such questions as seemed most likely to elicit the desired information, giving us the particular circumstances under which rupture occurred and the conditions that existed at the time.

From the reports made to us we learn that there is a wide difference in the quality of the water used in the boilers on the several roads, in regard to its purity and the deposits left in the boiler from its use.

That used in the boilers of the Lake Shore & Michigan Southern, Kansas Pacific, Eastern Division of the Terre Haute & Indianapolis, Western Division of the Pittsburgh, Fort Wayne & Chicago, and Northern Division of the Illinois Central Railroads, leaves heavy and solid deposits of scale on the heating surfaces. An analysis of the water used on the Northern Division of the Illinois Central shows that it holds in solution 84 grains of solid matter to the gallon. Now the five roads referred to have in use 656 steel fire boxes, and in these 105 side sheets, or 8 per cent. of the whole number, have ruptured within the past two years.

The other roads, using bituminous coal, where water of a medium or good quality is used in boilers, having an aggregate of 380 steel fire boxes in use, have had but 16 sheets ruptured, or 2 per cent. of the whole number of side sheets in them.

From these facts it would seem that impure water, from which heavy deposits of scale are formed on the sheets, has a very marked effect on the side sheets as regards their tendency to rupture.

We find also that with but a very few exceptions the water space, where rupture occurred, was but three inches. The sheets, except

in a few cases, were  $\frac{5}{16}$  of an inch thick. Those reported by the Fort Wayne & Illinois Central Railroads were, however, but  $\frac{1}{4}$  of an inch thick.

Mr. Sedgley, of the Lake Shore & Michigan Southern Railroad, reports that the water used in boilers on that road is obtained from lake, rivers, creeks, and surface reservoirs, and that it holds in solution lime, salt, magnesia, sulphur, etc., and these substances are deposited in considerable quantities on the heating surfaces of the boiler in the form of scale. On that road, with 304 steel fire boxes in use in coal-burning engines, 61 side sheets are reported to have ruptured within the past two years, and the scale on such sheets was about  $\frac{1}{8}$  of an inch thick. This thickness is doubtless greater than that usually formed on the side sheets, and may be the means of producing the forces that finally result in rupture. Out of 608 side sheets 61, or a fraction over, 10 per cent. have cracked.

On the Kansas Pacific Road, with 94 steel fire boxes in use, 10 sheets have ruptured, being about  $5\frac{1}{4}$  per cent. of the whole number of side sheets; and Mr. Waugh states that the scale on those sheets was about  $\frac{1}{8}$  of an inch thick, and composed mainly of carbonates of lime, alkali, salt, etc.

Mr. Peddle, of the Terre Haute & Indianapolis Railroad, reports that out of 50 steel fire boxes in use on that road 5 side sheets have ruptured, being 5 per cent. of the side sheets. He states that considerable scale had accumulated on those sheets, but the thickness could not be ascertained; most of it had been knocked off in cutting out the pieces preparatory to patching. An analysis of scale formed from the water used was made by Dr. Jenkins, of Louisville, Kentucky, in 1873, and shows it to have been composed principally of the carbonate of lime and magnesia, etc., with a considerable amount of alumina, some sulphate of magnesia, producing a very hard and solid scale.

On the Northern Division of the Illinois Central Road, where the water used in boilers contains 84 grains of solid matter to the gallon, the proportion of ruptured side sheets to the whole number in use is reported to have been six per cent.; but on the Chicago Division, where the water used contains but about 23 grains of solid matter to the gallon, the number of cracked side sheets to the whole number in use was a little over 2 per cent. On the Southern Di-

vision of this road, where about the same number of steel fire boxes are in use, and where no deposit is left in the boilers from the water used except that commonly called mud, not a single instance of rupture in a sheet has occurred.

The water used in boilers on the Western Division of the Pittsburgh, Fort Wayne & Chicago Railroad is reported to be similar to that on the Northern Division of the Illinois Central, forming a hard scale. The number of steel side sheets ruptured during the past two years was 21, or  $13\frac{1}{2}$  per cent. of the whole number in use. The water spaces were  $3\frac{1}{2}$  inches, sheets  $\frac{1}{4}$  of an inch thick,  $60 \times 62$  inches in size.

We find that on several other roads where the water, in regard to purity, is reported medium, the proportion of ruptured sheets to the whole number in use ranges from 1 to 2 per cent. In one case, however, that of the Little Miami, it is  $7\frac{1}{2}$  per cent.; and in another, the Jeffersonville, Madison & Indianapolis, the proportion is  $4\frac{1}{2}$  per cent. In these instances considerable scale had formed on the sheets that cracked, and we think it quite probable that in every case where sheets have ruptured in the manner stated, that more or less scale had previously formed on the sheet preventing the water from coming in contact with it, and as scale is a poor conductor of heat, the sheet in such a case is likely to have been injured by overheating, not from any direct action of the heat tending to change the nature of the steel, but from strains brought upon the different parts of the sheet by unequal expansion.

While the sheet is clear of scale it is in direct contact with the water, and while in that condition its temperature can not much exceed that of the water, and no injurious strains can be produced in any part of it from unequal expansion consequent on unequal temperature. *No instance is mentioned of a new and clean sheet having ruptured*, but only those that have been in use long enough to have accumulated more or less scale.

Your Committee have examined a large number of specimens cut from side sheets that have ruptured under different circumstances, and find a wide difference in the quality of the steel as it appeared at the time, ranging from that which could be doubled down cold without showing any fracture at the turn to that which could scarcely be bent at all without breaking. In some cases such pieces

were drawn under a hammer, then tempered and found to be hard enough to cut iron, while others would not receive a temper at all, showing that there was an original difference between the different sheets.

If none but sheets that show a large per cent. of carbon, and which are hard and comparatively brittle, were known to crack, we might attribute this peculiarity entirely to the nature of the steel in the sheet; but we find that sheets which were extremely tough, so much so that pieces cut out immediately alongside the crack could be bent cold, just as taken from the fire box and doubled down, the two parts coming together without showing a fracture at the turn, the turn running in a direction parallel with the crack and only about two inches from it, yet such side sheets have ruptured precisely in the same way and under the same circumstances as those in which the steel was hard and brittle. A case of this character came under the observation of one of your Committee a short time ago. The rupture occurred after the engine had been standing in the house eighteen hours, and while a stay bolt some two feet from where the crack started was being calked. The usual quantity of water was in the boiler which had not yet become entirely cold; the crack started at a hollow stay bolt, near the vertical center of the side sheet, about 8 inches above the grate, and took a vertical direction upward, but downward the direction was diagonal, the length being 20 inches, and the widest part in the crack was at the stay bolt at which it started (A, Fig. 1) and measured  $\frac{1}{3}$  of an inch. Parts of this sheet cut out, preparatory to patching, were doubled cold, just as taken out, in a direction so that the turn was parallel with the crack, yet no fracture at the turn was produced.

Now it would seem that metal showing such toughness as the pieces cut out alongside this crack could not be ruptured as this was, instantaneous and with a loud report. Yet these are the facts, and they accord with those stated in numerous other cases. We may infer then that the quality of the metal does not always prevent rupture, though the usual tests may show it to be of the very best.

Your Committee are of the opinion that a combination of several causes takes place previous to rupture, and that the proportions of the side sheets also have much to do with that tendency.

As stated before, in almost every case, it has been in the large

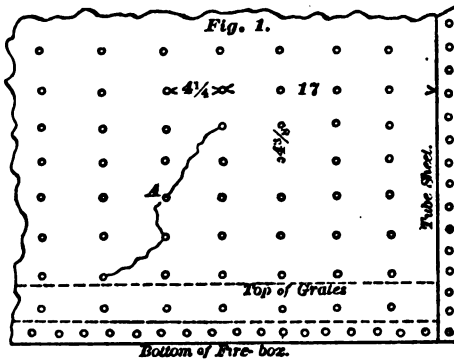


Fig. 1 represents the part of the sheet in which rupture occurred and the direction of the crack.

side sheets that rupture has occurred. Then we may inquire why these side sheets crack and not the other sheets in the fire box.

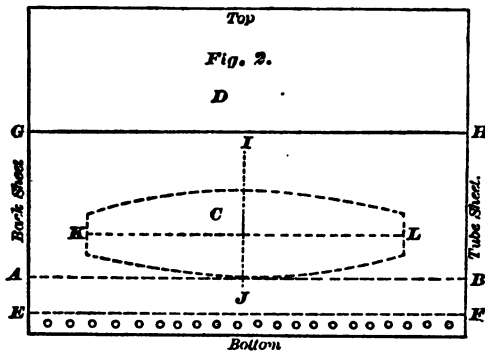


Fig. 2 will serve to illustrate by representing a side sheet, *D*. The line *A B* represents the top of the grate, *E F* the mud ring at the bottom of the fire box.

We believe we are correct when we infer that at times and under certain circumstances the part of the sheet for a short distance above the grate, and for the greater portion of the distance between the tube and back sheets, marked *C* in Fig. 2, will become hotter than the other portion of the sheet surrounding it, and if hotter then it will be under a strain of compression from the larger and cooler part of the sheet around it. What the difference in the temperature of the part

*C* and the balance of the sheet would be under the ordinary working conditions, we have no means of determining, but from the appearance of that part of the sheet, and of stay bolts in it in the fire boxes of coal-burning boilers, it is evident there is, at least at times, a marked difference. The point nearest where combustion is the most active will receive more heat than a point more remote, and as this part is immediately alongside the coal in the process of combustion it will necessarily receive the most heat, other things being equal. At such times, however, as when the gases evolved from the coal are undergoing combustion in all the space above it, and the combustion is more or less perfect, it is probable that no very great difference in the temperature of the sheet at points above the top of the coal will occur, but by irregular firing, or by throwing the coal on the grate in such a way as to permit the air to be drawn through it in certain spots or holes not far from the sheet, it is evident that great changes of temperature at those particular places will occur, and that such changes will also affect to some extent the part of the sheet nearest to them. While the difference in temperature between different portions of the sheet are only such that the strains brought upon them by the corresponding difference of expansion does not exceed the elastic limit of the metal, no injury is likely to result. Now if the sheet *D*, Fig. 2, was originally free from strain in all parts of it, and the part *C* from unequal heating becomes of a higher temperature than the part surrounding it, then, as stated before, it will be under a strain of compression; and if the temperature of *C* is further increased above that of the other portion of the sheet until, if free to assume a length through *K L* due to its temperature, it would be  $\frac{1}{8}$  of an inch greater than the other part of the sheet will permit, and the elastic limit of *C* in that direction is but  $\frac{1}{16}$  of an inch, then *C* will be permanently shortened  $\frac{1}{16}$  of an inch, or the part of the sheet surrounding it will be lengthened to that extent; but as the part *C* is smaller in section through *I J* than the larger part and the mud ring to which it is riveted, *C* is much more likely to be permanently shortened through *K L* than that the whole sheet will be elongated in the direction of and through *G H*, in which event *C* will be under a tensile strain in that direction when the whole sheet becomes uniform in temperature to the same extent that it was under compression in the former case; but as the elastic limit of *C* is  $\frac{1}{16}$

of an inch in the direction of  $KL$  and as  $C$  only lost permanently  $\frac{1}{8}$  of an inch of the  $\frac{1}{2}$  referred to in the first instance, then when the whole sheet becomes cold, or of the same temperature in all its parts,  $C$  will be under a tensile strain to the extent of what its permanent loss in length was in the first instance,  $\frac{1}{8}$  of an inch, and equal to the elastic limit of the metal.

Within the limits of the varying temperature to which a fire-box sheet is subjected, the expansion and contraction may be said to observe a uniform rate being in proportion to temperature.

Experiments made by Fairbairn and others a few years ago, demonstrated the fact that the elasticity of steel began gradually to decrease as the temperature was raised above 252 degrees, Fahrenheit, or about 100 degrees less than the temperature of the water, with steam at the usual working pressure.

It was also discovered that repeated application and removal of a load which is considerably below the breaking weight of the metal, will, after a number of such repeated applications, cause fracture.

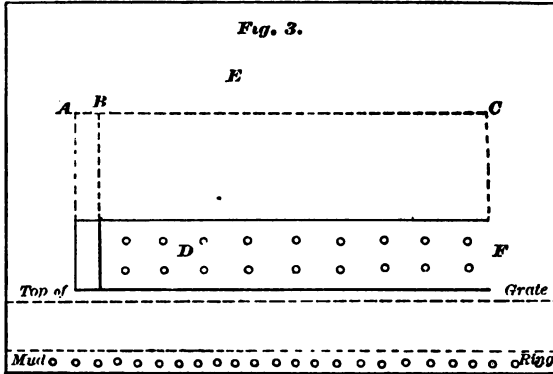
If this be true, and if we remember that in the case of steel sheets, this load is not only removed, but is applied in the opposite direction at alternate heatings and coolings, the causes that result in rupture would seem to be apparent.

If the theory of expansion referred to is correct, then every time a part or spot in a sheet attains a higher temperature than that surrounding it, the metal in it is under a strain of compression; and if that strain is beyond the elastic limit of the metal in that part or spot, it is permanently reduced in area by such compression, and then when the whole sheet is cold alike such part or spot is under a tensile strain, so that these alternate forces are constantly produced in the sheets that are unequally heated in their several parts.

Steel, as is well known, will bear great tensile strain, and can be elongated to a considerable extent before breaking, provided the strain is confined to one direction, but like iron, will break sooner or later if the strain is applied in alternate directions to an extent closely approaching the limit of elasticity of the metal.

$E$  represents a side sheet of a fire box, with a part immediately above the grate marked  $D$  cut from it, and independent, except at the end  $F$ , and corresponding with  $C$ , Fig. 2; the free end of  $D$  being at the line  $B$ . Now if we assume the distance from  $B$  to  $C$  is

one hundred inches, and the temperature of *D* is raised to the extent that the expansion of *D* is one unit per inch greater than *E* along *B C*, and that *B* has then reached *A*, then the distance from *A* to *B* will represent 100 units of difference of expansion.



For further explanation of the effect of unequal temperature in a sheet, Fig. 3 will illustrate as between a long sheet and a short one.

Now if *D* had been attached at *B*, so that the movement toward *A* could not have taken place, then the 100 units' expansion referred to would have been absorbed in the elasticity of *D*, between *B* and *C*, under compression; but if the sheet is reduced in length, and the distance from *B* to *C* is but fifty inches, then, under the former conditions of temperature, *B* would move but half the distance toward *A*, or 50 units; and if *D* had been attached at *B* only the 50 units would be absorbed by the elasticity of *D* under compression; but the extent of compression in the one case, *for each inch in the length of D*, is the same as in the other, 1 unit. Now if *D* is of the same sectional area at all parts of its length, and of equal strength to resist compression and elongation, then the result would be the same, whether the distance from *B* to *C* were 50 or 100 inches; but as numerous stay bolts are situated in *D*, the sectional area across it vertically through the stay bolts differs from that between them, and when the greatest strain of compression is exerted in *D* it is the least elastic; and may lose a fraction of its original length on that account. If so, then when cooling off and heating, alternate



strains are exerted in turn, and if some one section across *D* is or becomes weak and less able to bear these strains than the other points, then in the case of the long sheet there would be 100 units of elastic force, or a portion of them, that would tend to *accumulate* at such weak point, the same as occurs when compression or tensile strain is applied to a bar of metal which is smaller at some one point, and of course weaker than at others. If such force is greater than the elastic limit of this weak point, then the whole of the permanent change occurs there—it accumulates there—and as this accumulation in *motion* or *extent* (but not in force) is greater in the case of a long sheet, so is the danger of rupture or injury from expansion and contraction in the part subject to the greatest variation in temperature, most likely near the vertical center line.

In the use of large vertical sheets in a fire box these alternate strains are constantly occurring with the change from the working temperature to that when the boiler is cold, or nearly so, as we have endeavored to show, and it is safe to conclude that these strains in alternate directions (compression and elongation) finally result in the minute cracks so frequently found extending mostly in a vertical direction from the stay bolts in that part of the sheet subject to the greatest heat.

As previously stated, if the part *C*, Fig. 2, has been overheated it will be under a tensile strain when cold, or at as low a temperature as the other portion of the sheet, and that such strain may be so great as to equal the elastic limit. Now, with a tensile strain in the direction of *K L*, Fig. 2, to that extent, and one or more small cracks extending in a vertical direction from one of the stay bolts situated somewhere near that line, it is not difficult to understand how or why rupture sometimes takes place. As stated before, we have not heard of a single case where a perfectly clean sheet has ruptured, and from our investigations and observation we are led to believe that the principal cause which finally results in rupture of the sheet is the formation of more or less scale on the water side of it, preventing the water from coming in direct contact, and as scale is a poor conductor of heat the metal of that part of the sheet represented at *C*, Fig. 2, owing to its close proximity to the intense heat of the coal on the grate attains a higher temperature than the other parts more remote, and as it can not assume the proportions due to

its temperature, the metal is "upset" or shortened while at a high temperature, and when the whole sheet becomes cold then the tensile forces are developed and exert their influence as heretofore explained, and result ordinarily in occasional leakage at the stay bolts situated in that part of the sheet, and sooner or later in developing the small cracks so often found extending from the stay bolts to the distance of one-half an inch or more in a direction mostly at right angles to the line of strain, and at times, under favorable conditions, result in rupture of the sheet.

The theory that the formation of scale is injurious to the sheet, on account of it attaining in that condition a higher temperature than if clean will, perhaps, not be called in question, and it will account for the fact that rupture occurs so much more frequently in the sheets of boilers in which water is used that leaves heavy deposits of scale than in those in which purer water is used, as was seen in the results on the Northern, and that on the Southern, Division of the Illinois Central Railroad, and also in the number of ruptured sheets in the fire boxes in use on the Western Division of the Pittsburgh, Fort Wayne & Chicago Railroad, and that of the Boston & Albany Railroad, where but one steel side sheet ruptured within two years of the two hundred in use.

The formation of scale in narrow waterspaces will, doubtless, result in injury sooner than where the spaces are wide, permitting a larger body of water and better circulation.

Injurious temperature need not be continued for any considerable length of time to be productive of bad results in a sheet for the reasons heretofore given. A few minutes will accomplish the same result as if continued for hours.

From the replies to our circular we learn that a very small proportion of sheets have ruptured in the long and comparatively shallow fire boxes in which anthracite coal is burned. This may be accounted for from the fact that the sheets are comparatively narrow, vertically, and the grates at no very great distance from the crown sheet, and when in working condition there can be no great difference in the temperature of the sheet at the different points between the grate and crown sheet on that account, and if all parts of the sheet are of nearly the same temperature no such changes from

unequal expansion as that referred to in Fig. 2 can occur, therefore the tendency of such sheets to rupture should not be so great.

On the other hand we find that rupture is confined almost exclusively to long and deep sheets. The reasons why it is more likely to occur in this class than in the former, is the possibility of there being wide differences in the temperature of different parts of the sheet at the same moment; these reasons we have heretofore given and explained in Fig. 2. The longer the sheet in the direction of the length of the boiler the greater the danger of final rupture, provided the sheet is proportionally deep.

We learn from the reports made to us from the different roads that sheets have ruptured under nearly all circumstances, except when the boiler was under steam and with fire on the grate. From the theory advanced above there ought not to be much tensile strain on the part of the sheet liable to rupture under this condition, and no case of this kind has come to our knowledge. Rupture has frequently occurred when the sheet was cold, or nearly so, and after cooling down. In answer to the question: Why it is then likely to take place? we offer this an explanation: After the water in the boiler ceases to boil all circulation from that cause ceases, and the coolest water finds its way to the lowest point on account of its greater density. Now both sheets forming the waterspace around the lower part of the fire box are exposed to the air, and as the body of water there is small it will cool off much faster than above, near the crown sheet, where the body is much greater and where the outside sheet is covered with a jacket; and, as it cools faster at the bottom than at the top, no circulation whatever takes place, and thus a wide difference between the temperature of the water at the bottom of the fire box and that near the top is likely to occur at each cooling down. The temperature of the sheet if free from scale will correspond with that of the water in contact with it, but if covered with heavy scale it will cool faster and be at a lower temperature, and it is the force developed by this difference in temperature between the upper and lower part of the fire box, added to the tensile strain in the part C, Fig. 2, which was previously produced from other causes, that is likely to rupture the sheet. Sheets have ruptured when there was no water in the boiler; but in all cases, so far as we know, it occurred soon after the water had been run out; and if the

water was of a higher temperature than the atmosphere at that time the sheet would cool off in this case much the same as in the former, the upper part cooling slowest, and the result as to additional strains would be of the same character.

Filling a boiler with water of a lower temperature than the metal of the sheets has produced rupture in a large number of cases, and is the result of the contraction of the metal through  $K L$ , Fig. 2, when the water reaches and cools it, while the part through  $G H$  is still at a higher temperature. Several cases are reported where rupture occurred after starting a fire in the engine and before steam was raised.

Now it would seem that if the metal along  $K L$  was under tensile strain in that direction, previous to starting a fire, that the heat imparted to it immediately afterward would commence to relieve that strain, and that rupture of the sheet could not occur under such circumstances. One of your Committee made some experiments a short time ago to determine the effect of heat applied to the outside of the sheet, in heating the water in the waterspace, as regards the temperature of the water at different points between the bottom and top, during the time the water was being heated to the boiling point. A waterspace was constructed  $2\frac{1}{4}$  inches wide, 18 inches high, and 16 inches long. The sides were of  $\frac{1}{8}$  of an inch sheet iron, and the ends between the sheets were made of plate glass  $\frac{1}{2}$  of an inch thick. This waterspace formed one side of a square iron box, having a chimney on top and a grate in the bottom; the top of the grate bars being 1 inch above the bottom of the waterspace.

This space was filled with water at a temperature of 50 degrees. A thermometer was introduced into the waterspace, attached to a wire, so as to be raised or lowered in the column of water when desired; the glass ends of the waterspace admitting of the reading of the thermometer at any point in the height of the column. The waterspace occupied the same position in this iron box as that in the side of an ordinary fire box. A charcoal fire was built on the grate, and after a few minutes the thermometer, with the bulb in a line with the top of the grate, showed a temperature of 55 degrees, and being raised with the bulb just under the top of the water, showed a temperature of 80 degrees, and when the temperature at the top of the grate was raised to 60 degrees, at the top it was 120

degrees, and after reaching 120 degrees at the bottom the temperature at the top was 180 degrees. The temperature at intermediate points between the top and bottom showed a gradual increase from the bottom upward, in proportion to distance.

As soon as the water commenced to boil in the upper part of the waterspace the temperature at the bottom rose rapidly to the boiling point.

Several tests were made in heating the water from 50 degrees to the boiling point, with results varying but little from that given.

From these tests we learn that after a fire is started on the grate the temperature of the water in the upper part of the waterspace increases more rapidly than that at the bottom, and that the difference is at certain times as much as 60 degrees.

Now this difference of temperature between the upper and lower part of the sheet produces the same results, as affecting the previous tensile strain in the direction of *K L*, Fig. 2, that is produced by cooling down, or by putting cold water in the boiler while the sheet is at a higher temperature than the water, and if rupture can be produced in the latter cases it may also in the former. In cooling down there was not so marked a difference between the temperature at the top of the water and at the bottom. The waterspace being open at the top and exposed to the air, the temperature there would naturally fall faster than under the circumstances that exist in a boiler. A test with the thermometer, however, showed that when the temperature of the water was 122 degrees at the top the temperature at the bottom was 114.

With two exceptions, in all the cases of ruptured sheets reported, not one is mentioned in which the crack took a horizontal direction, some have been diagonal a part or all of the distance, but none horizontal. This may be accounted for from the fact that the line of greatest heat extends entirely around the fire box, parallel with the grate, and is doubtless a comparatively narrow section compared with the total distance between the grate and crown sheet; therefore the temperature on any one line around the fire box at a given height above the grate will not greatly vary, except that it will probably be less in the corners than on a line up the centers of the sheets, and strains produced from unequal vertical expansion of the sheets can not be of such magnitude as to cause rupture on a horizontal line;

yet in the portion of the side sheet represented at *C*, Fig. 2, and also a corresponding portion in the end sheets will, when cold, be under a tensile strain in the direction of *I J*, which was originally produced by the same causes that produced that in the direction of *K L*, but of less proportions for reasons given above; but if the temperature of the sheet at the corners of the fire box always corresponded with that on a line at the centers of the sheets, no vertical strain whatever could be produced in any part of the sheet. It is only to the extent that the temperature of the corners differs from that along the center of the sheet that any vertical forces can be produced.

Now if rupture occurs at some point along *K L*, Fig. 2, from strain in that direction, the crack will be vertical in that direction its entire length if no force is exerted in the direction of *I J*; but if the metal is under a tensile strain in that direction also, the crack will take a diagonal direction, corresponding with the extent of the two forces.

As previously stated, all cases of rupture coming to our knowledge had their origin in some one or more small cracks at a stay bolt, and from this beginning, when the sheet was under great tensile strain, the crack started, and when started, what is known as the "shearing process" comes into play—one particle of the metal after another giving way in succession, yet all being done instantly—extending the crack beyond where the forces were sufficiently great to *initiate* a crack.

To explain why one sheet cracks and many others used under precisely the same circumstances do not, would be as difficult as to explain why one leaf of a spring made from the same bar as the others, and tempered, tested, and used precisely the same as all the others, and the same as those in many other springs like it, breaks, and yet none of the others do. There is, doubtless, a difference in some respect, yet it might be impossible to discover it.

A reasonable and as we believe a correct answer to this question is, that the metal in *C*, Fig. 2, is gradually reduced in area to a slight extent, principally in the direction of *K L*, from the causes heretofore explained, but still remains of such area that when the sheet is at its usual working temperature it is under some strain of compression, while the part around it is under the opposite strain. The metal being elastic to a certain limit, *C* is slightly compressed, and

*D*, Fig 2, elongated, and when cold, *C* is elongated, and *D* (or the remainder of the sheet) is compressed, the result of each in its effort to accommodate itself to the forces or influence of the other; and that ordinarily these forces so adjust themselves that they remain under all the circumstances of varying temperature much within the elastic limit of the metal, and in this condition they may be continued indefinitely without injurious results.

From our investigation of the causes that often results in rupturing the large sheets of fire boxes, we conclude that some forms of corrugation of that part liable to the destructive forces referred to will be most likely to be successful in preventing it. Such corrugations need not extend perhaps more than thirty inches above the grate to answer the purpose intended. We think it probable that four or five slight vertical channels between the alternate rows of stay bolts in the side sheets, and one or two in the back and tube sheets, will be found equally effectual. It is the tensile force only that results in rupture, or ordinarily, what is nearly as bad, in small cracks at stay bolts, and more or less leakage there, and if we provide a relief for that strain when it exerts its force, then rupture or injury to the sheet can not occur, and the form of the sheet at the part *C*, Fig. 2, that will relieve a tensile strain in the direction of *K L*, will also relieve that of compression in the same direction. As rupture or injury of stay bolts occurs in no other part of the side sheet than *C*, Fig. 2, it would seem to be unnecessary to provide relief for these strains in any other part, and the several slight channels or corrugations referred to above, crossing this part *C* vertically, between the rows of stay bolts, with the channel in the water side of the sheet, should, by the spring of the curve of the corrugation, relieve indefinitely all strains produced by unequal expansion or contraction, without any danger of rupture or injury to the sheet. Such corrugations need not perhaps be more than the thickness of the sheet in depth, beginning gradually and ending the same; and if properly annealed, the sheet will be left entirely free from the strain developed in corrugating it, and of a form to be easily fitted to the other parts of the fire box, and curved as may be desired.

Your Committee would submit as a part of their report the following from Mr. S. J. Hayes, one of the members of the Committee,

as expressing his views on the different subjects alluded to, in which all the other members fully concur and indorse :

CHICAGO, May, 1st, 1876.

R. WELLS, Esq., *Chairman of Committee :*

DEAR SIR—Of the three materials used for furnace sheets of locomotives, copper, iron, and steel, I prefer steel; but plainly see the necessity of urging the manufacturers to make it soft, ductile, and homogeneous, because the higher the grade of steel the greater its liability to crack after being put in service. I take it for granted that all members of our Association are aware that each of the three materials named is objected to by different Master Mechanics for the following reasons :

Copper, because it is too expensive; iron, because it is liable to blister or crack; steel, because it is liable to crack.

These are the main points which, in my opinion, should be borne in mind in dealing with these materials for furnace sheets.

So much has been said and written on the subject of copper and steel furnace sheets in past years that I do not think our Committee should occupy the time of the Association by again repeating it, but should endeavor to present a few new facts in relation to *steel furnace plates*. What we all want to know is the effect of fire and water on steel plate.

About one year ago I conducted the following experiments, which will, perhaps, be of interest in this connection :

A piece of "open-hearth" steel plate  $\frac{5}{8}$  of an inch thick and  $9\frac{1}{2}$  inches square was heated to a cherry-red heat, and dipped in cold water six successive times, after which the edges were found slightly rounding; that is the sheet measured exactly  $9\frac{1}{2}$  inches across the center, but very little less across the edges, showing that the contraction in this case was along the edges of the sheet.

After being heated and cooled, as described, the steel was quite soft and was bent double, cold, without fracture. Two tests of its tensile strength was made with the following result :

No. 1 stretched  $\frac{3}{8}$  of an inch and broke at 80,914 pounds per square inch.

No. 2 stretched  $\frac{3}{8}$  of an inch and broke at 74,057 pounds per square inch.



The average being  $77,485\frac{1}{2}$  pounds per square inch.

To see if the heating and cooling for six successive times had affected the strength of the plate, two samples cut from the same part of the same sheet as the  $9\frac{1}{2}$  inch piece were tested; these samples were not heated and cooled, but were taken from the sheet just as it came from the mill. The following was the result:

No. 1 stretched  $\frac{3}{8}$  of an inch and broke at 67,200 pounds per square inch.

No. 2 stretched  $\frac{7}{8}$  of an inch and broke at 64,475 pounds per square inch.

The average being  $65,837\frac{1}{2}$  pounds to the square inch.

The tensile strength of the steel having been increased  $17\frac{7}{10}$  per cent. by the heating and cooling described. It seems probable that the increase in tensile strength was accompanied by increased hardness, but yet the steel bent double, cold, after being heated and cooled six times.

In the year 1871 the Committee of which I was chairman, gave the average tensile strength of three pieces of  $\frac{1}{8}$  inch steel plate, 71,167 pounds per square inch of section.

The steel tested was what is known as "crucible steel." The "open-hearth" steel seems to be softer and more ductile, but of less tensile strength than the crucible steel, which was tested and reported to this Association five years ago. The tests were made at the shops of the Illinois Central Railroad under my supervision.

Careful observation has, to my mind, demonstrated that the nature of the water used in locomotive boilers has a great deal to do with the life of steel furnace sheets. The liability to crack increases with the impurity of the water used in the boiler. Roads troubled with heavy formations of scale in boilers have also greater trouble from the cracking of steel furnace sheets than have those roads along whose line the water is comparatively pure and whose boilers are free from scale. I presume you have considerable information on this particular point, and may deem it necessary to give it in detail. I therefore state the following facts which strongly support the conclusions stated:

The Illinois Central Railroad is about 1,100 miles long, about 700 miles being in the State of Illinois and 400 miles in the State

of Iowa. On this line the greatest deposits of scale are formed in the boilers of locomotives employed on the North Division, which is 225 miles long. I have lately tested the water from two water stations on this Division with the following result:

Mendota station 84 grains of solid matter per gallon of water.

Rutland " 70 " " " " " "

Number of engines on the Division, 49.

During two years ending March 31st, 1876, six crucible steel side sheets, and one Low Moor iron side sheet, have cracked on this Division.

On the Chicago Division of the same road water was tested from five stations with the following result:

Chicago, 18 grains of solid matter per gallon of water.

Kankakee, 20 " " " " " "

Gilman, 15 " " " " " "

Champaigne, north tank, 20 grains solid matter per gallon of water.

Champaigne, south tank, 34 grains solid matter per gallon of water.

Number of engines on the Division, 69.

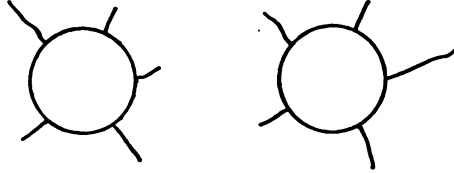
During the two years ending March 31st, 1876, three crucible steel sheets have cracked on this Division.

I invite your careful consideration to the foregoing facts, which point directly to impure feed water as one of the prime causes of failure in steel furnace sheets. Frequent washing out, with a good force of water, and prompt removal of incrustations are the remedies. The use of surface or other pure water is the only sure preventive, and the day will come when railway managers will see that "prevention is better than cure."

A freight locomotive with 16×24 inch cylinders will use about 6,000 gallons of water per day, or 1,800,000 gallons per year of 300 working days, and assuming that such an engine used for 300 days the water from Mendota station, we find that 21,600 pounds of solid matter would be precipitated in the time specified.

Of course, the greatest portion of this would be removed by the frequent washing out of the boiler, customary upon all roads, but there would remain on the flues and furnace sheets large quantities of incrustation, detrimental to those parts of the boiler, and to its

steaming capacity. On roads where boiler incrustations are heavy, it is common to see a number of small cracks in steel furnace sheets, radiating from the stay bolts, as shown in these sketches.



For lack of a better name, we call these "mud cracks," and find them from  $\frac{1}{2}$  inch to  $1\frac{1}{2}$  inches long; sometimes they leak a little, but on being drilled, tapped, and plugged with several small-copper plugs, will run for several years; others, and, in fact, nearly all these small "mud cracks" do not leak at all. It is probable that the accumulation of scale around the stay bolts is the immediate cause of these small checks or cracks. The scale on one side of the sheet, and the fire on the other, produce the result described.

Allowing for the cracking of steel furnace sheets, and the expense of patching or replacing them, I must say that I am still of the opinion that steel is the best material to use for this purpose, but I again say that manufacturers must devote their attention to making steel of low grades—soft, ductile, and homogeneous.

For the outside shells of locomotive boilers I think steel plates should be used. In regard to the form and proportion of boilers we have nothing new to offer. The ground has been canvassed yearly for the last seven years, during which time straight and wagon-top boilers have been discussed; so, also, have water tables and fire-brick arches, and a few other appliances. The facts and figures in relation to all these have been placed before the Association, and now form a part of its records.

I do urge, however, the importance of large furnaces for coal-burning engines; the use of flues not less than eleven feet in length; the admission of air above the fire, through hollow stay bolts, or tubes provided for the purpose; the use of  $\frac{1}{4}$  inch steel or  $\frac{5}{8}$  inch iron for sides, back, and crown of furnace, and  $\frac{3}{8}$  inch steel or  $\frac{7}{8}$  inch iron for back flue sheets. The use of small smoke boxes will also be found advantageous.

[ In conclusion, I would recommend that all steel sheets should be annealed after being flanged, and I think all holes, in steel plate, should be drilled.

Yours truly,

S. J. HAYES,

*Sup't of Machinery, Illinois Central R. R.*

#### RENEWAL OF FIRE BOXES.

From the reports of 1,272 coal-burning engines having steel fire boxes, we find that but fifteen are reported to have had their fire boxes renewed on account of the old ones becoming unserviceable from small cracks at stay bolts, rivets, and from general deterioration. These fire boxes had been in use from four to seven years, and had made the following mileage: one made 95,000 miles; one, 118,000 miles; five averaged 125,000 miles each; four averaged 140,000 miles; one made 154,000 miles; two averaged 188,500 miles, and one, mileage not given. The average for the fourteen given is 137,700 miles each.

The highest mileage given of a steel fire box which is still in good condition, is on the Old Colony Railroad of Massachusetts, in a passenger engine, which has made 280,000 miles, and one in a freight engine that has made 245,000 miles. The North Pennsylvania Railroad reports a mileage of 250,000 in passenger engines and 123,000 in freight, and the fire boxes still in like good condition. The Central Railroad of New Jersey reports steel fire boxes on that road as having made a mileage in passenger engines of 235,000, and in freight engines, 212,000 miles, which are still in good condition and free from cracks.

The Terre Haute & Indianapolis Railroad report a mileage of 184,000 in passenger, and 208,000 miles in freight engines, and the Jeffersonville, Madison & Indianapolis Railroad 200,000 miles in passenger, and 150,000 in freight engines, the fire box sheets of which are still free from cracks and in good condition. The Little Miami Railroad reports a mileage of 200,000 with steel fire boxes, which are in like good condition.

The Lake Shore & Michigan Southern Railroad gives a mileage of 136,000 in passenger, and 163,000 miles for freight engines, in which the steel fire boxes are yet in good condition. Other roads,

reporting the mileage of their steel fire boxes, which are still in good order, give it from 100,000 to 180,000 miles. From the experience had with steel fire boxes on the roads making report to us, the conclusion is reached by them that, on roads where good and comparatively pure water is used, such as the North Pennsylvania and Old Colony Railroads, 300,000 miles may be considered the average lifetime of a fire box before renewal is necessary. A number of other roads that report the quality of water used as medium, state that on their lines 250,000 miles may be considered a good average mileage for the lifetime of a fire box ; and those roads that report using water that contains large quantities of lime and other impurities, as the Lake Shore & Michigan Southern and Kansas Pacific, state that, on the latter 150,000 miles in passenger and 120,000 in freight engines is about the average lifetime, and on the former road 200,000 miles is a good average for a steel fire box.

From the above we conclude that the character of the water used in a boiler will determine, to a great extent, the lifetime of a fire box, rather than simply the work done.

The data in regard to iron fire boxes in which coal is burned is so incomplete that we can not give figures or information sufficient to warrant any comparison with steel. Mr. Chas. Graham, of the Bloomsburg Division of the Delaware, Lackawanna & Western Railroad, states that he has iron fire boxes, with corrugated side sheets, in the anthracite coal-burning engines on that road, which have made a mileage of 183,000 miles, and which are, to all appearances, still perfect.

Corrugated steel sheets for fire boxes are now being largely used on the Chicago & North-Western Railroad, and, it is stated, with good success. We are sorry to say, however, that we have no report from the officers of that company in regard to its merits. Mr. Jas. Sedgley, of the Lake Shore & Michigan Southern Railroad, reports that he has twenty fire boxes with corrugated steel sheets, all of which are doing well. The greatest mileage made by any of these is 27,000. Corrugated steel is being used for the side sheets on several other roads to a limited extent, but the test has not yet been sufficient to determine the value as compared with plain sheets.

We have been unable to get sufficient data in regard to the expe-

rience had with copper used for fire box sheets to enable us to make any comparisons with that of iron and steel.

#### THE BEST FORM AND PROPORTIONS.

In our investigations of the above subject, your Committee directed their inquiries with the view of ascertaining what changes in the form and proportions of the ordinary boiler and fire box in use were requisite in order to obtain better and more economical results in the consumption of coal.

In the replies received no material change in the form of the boiler or fire box is recommended from that in general use. For anthracite coal the long and comparatively shallow fire box is considered the most economical, and for the use of bituminous coal a large and deep fire box is almost universally conceded the best.

Those who have had considerable experience in the use of what is known as the Weston boiler, state that this form of boiler has not proved to be more economical in the use of coal than the ordinary plain fire box. The same statement is also made in regard to that form known as the Jauriett fire box.

In designing the form of a fire box, it should be borne in mind that a large portion of the heat received by the heating surfaces is radial; that is, it is not carried to the sheets by currents of heated gases, but is received as rays, the same as light; and these heat rays will not bend around a corner any more than the rays of light. Now, if a water table or brick arch is placed in the fire box, these heat rays that come from the fuel in combustion on the grate will be cut off from the upper forward portion of the fire box—those parts being in the shade, as it were, as regards the rays that emanate from the vicinity of the grate. In the case of the water-table, its lower surface would receive these rays cut off from the upper part, and the brick arch would reflect them to the sheets back of it. Yet, on the whole, nothing is gained by the use of either arrangement, so far as the radiant heat from the combustion going on in the lower part of the fire box is concerned. To that principle, then, we may attribute the fact that an increase of heating surface is not always followed by a corresponding increase in beneficial results. The opinion expressed, however, is almost unanimous that a

larger fire box would result in increased economy in the consumption of fuel.

Some recommend that the fire box be lengthened as much as the spread of the driving wheels will admit of, even at the expense of shortening the tubes to that extent, where bituminous coal is used as fuel.

Your Committee do not consider that mere opinions on such points are of much value, unless based upon the results of careful experiments; and no data of this sort has been furnished us, therefore we can form no conclusion as to the exact number of feet of fire-box heating surface, and tube surface, best adapted to furnish steam economically for a given size cylinder in a given time.

This matter is one of as much, or more, importance than any other in furnishing power; and, at the same time, our positive knowledge as to the best proportions, area of fire box, length, size, and number of tubes that can be arranged and adapted to the present style of locomotive in use in this country, is less than that upon any other subject connected with the use and management of the locomotive. Are the proportions as now generally adopted for boilers intended to burn bituminous coal the best possible? If not, what should they be? Should the fire box be longer, or shorter and wider? and how much? Where is the limit? Would it be economical to lengthen the fire box at the expense of shortening the tubes? If so, to what extent? Is a three inch water space on the side of a fire box more economical in the use of fuel than a three and a half inch space? Should the side sheets of the fire box be curved outward above the frame, or should they be perfectly straight and vertical, or should they incline toward the center at the top—proportionally reducing the area of the crown sheet?

These are questions that naturally suggest themselves, but we have been unable to obtain any information on these points based upon actual tests, and until they are made in a careful and thorough manner, with the view of obtaining all the facts relating to the points referred to, changes from the forms and proportions now in use, that would result in economy, can not with certainty be pointed out. In view of their importance, we would recommend that special attention be given to these matters during the next year.

Some observations made by one of your Committee on the effect

produced by inclining the side sheet of a fire box, as regards the course of the steam globules as they pass upward in the waterspace, may not be without interest to some of our members.

The waterspace with glass ends, referred to previously in this report, was used for the purpose. As before stated, this waterspace formed one side of a square iron box, with the top of the grate one inch above the bottom. With clear water, the view through the waterspace and the plate glass ends was perfect, and the formation of the steam globules on the side of the sheet of iron next the fire, and their course upward through the water, could be seen with great perfection. Before the thermometer indicated 120 degrees at the top, infinitely small white globules formed and passed upward close to the surface of the sheet in unbroken streams, yet no movement of the surface of the water could be detected nor vapor seen. As the heat increased and the water boiled, the size of the steam globules increased also, and in their ascent they extended farther out into the column of water, and the greater the heat and violence of ebullition, the farther these steam globules seemed to be repelled from the sheet where they were formed, and the more thoroughly they mingled with the whole body of water in the space. The motion of these steam globules seemed to be to a considerable extent independent of the motion of the water through which they ascended, as could be easily determined by introducing particles of wood into the boiling water. The principal agitation of the water was at the top, mostly in the first two inches in depth, that below remaining comparatively quiet, so far as currents were concerned, notwithstanding the clouds of steam globules that rolled upward through it, often in graceful curves, the same as if floating through air. As stated above when ebullition was the most violent the steam globules were largest, some of them as large as  $\frac{1}{4}$  inch in diameter, seeming to come out from where immense numbers of smaller ones were passing upward, and to have been formed from a number of smaller ones, as a large drop of water results from the union of small ones. These large round globules would sometimes strike the outside sheet and rebound or roll along the sheet upward, then bounding from it back through the water as if highly elastic, as if passing through air, and disappearing at or near the surface. The large globules referred to were not seen to form at any point except where the temperature of the



sheet was probably the greatest, about the height of the top of the coals on the grate or a little above that.

When the water boiled slowly the best opportunity was afforded for observation. At such times the steam globules ascended in a quiet stream near the sheet when perpendicular, gradually diverging from it as they neared the top, until at that point they filled the entire waterspace.

When the waterspace was inclined toward the fire the globules took a vertical direction, and diverged from the sheet more rapidly; and when the incline was outward, or from the fire, the tendency of the globules was to pass up in close proximity to the sheet until near the top, when in all cases they diverged so as to fill the whole space. When ebullition had nearly ceased, or was just beginning, it was always observed that wherever there was a spot on the surface of the sheet that was perfectly clean and clear of the usual hard scale of sheet iron, the clean raw iron being in contact with the water, that at every such spot small steam globules were thrown off in continuous streams, like the leakage of steam through a porous substance, while at all other parts of the surface, where the sheet had the usual smooth hard iron surface, scarcely any globules would be found, showing that much more heat passes through into the water at points where the clean raw metal and water are in contact than where the conditions are otherwise.

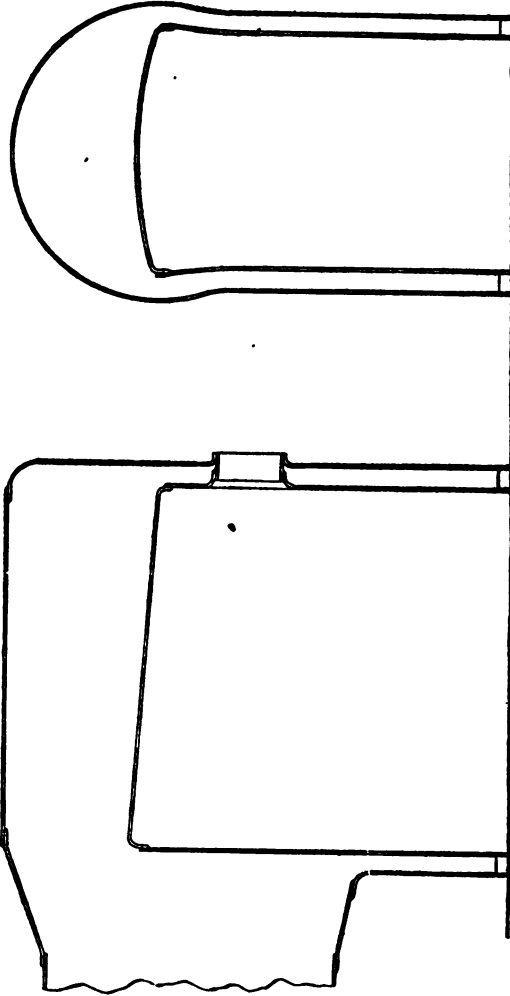
The action of water under a steam pressure, when steam is being drawn from the boiler as fast as it will generate it, can not be materially different, so far as the formation and movement of steam globules is concerned, from that taking place under pressure of the atmosphere only. In either case all passes off that the heat will generate under different conditions.

We are led to believe, from a close observation of the formation of steam globules at spots where the water comes in direct contact with the metal, and that at others where the contact is less perfect, that if the heating surfaces could be kept perfectly clean that a very marked saving of fuel would result as well as economy in boiler repairs.

We append, as a part of our report, a sketch (Fig. 4) of the form of fire box adopted by Mr. J. Johann, Master Mechanic of the Toledo, Wabash & Western Railway, and as used by Mr. Boone, on

**SECTION OF FIRE BOX, SHOWING CROWN SHEET.**

Western Division of the Toledo, Wabash & Western Railway.



*Figure 4.*

the Western Division of the Pittsburgh, Fort Wayne & Chicago Railroad. The crown sheet slopes backward from the tube sheet, at the rate of about one inch per foot, and it has also the form of an arch with a slope of three inches from the center towards the sides. Mr. Johann states that this form, to a great extent, prevents the permanent lodgment there of scale and dirt.

#### ADMISSION OF AIR TO THE FIRE BOX.

To the question in regard to the admission of air to the fire box through hollow stays or tubes, the replies received show that this is being done almost universally where the bituminous coal is used. Such hollow stays or tubes entering the fire box at points from twelve to eighteen inches above the grate, and their aggregate area in most cases, compared with the area of the stack, is as 1 to 45. In one case, that of the St. Louis, Vandalia, Terre Haute & Indianapolis, Mr. Peddle states that his practice is to make them as 1 to 18, and finds the result to be satisfactory in a better consumption of the gases, and consequently less smoke from the stack. Another member of your Committee is using such tubes, mostly in the back sheet, and twelve inches above the grate, of the proportion of 1 to 25, with equally satisfactory results. We are not prepared to say that such admission of air results in any marked saving of fuel, but the result appears to be a better consumption of the gases, that otherwise are an annoyance in the form of smoke. The kind and quality of coal used will determine the quantity of air that should be admitted above the grates in order to produce the best results, and it is quite probable that difference in coals will require a corresponding difference in the quantity of air requisite to produce the best results in their consumption, in producing heat, and so far as possible, avoiding smoke.

The question is sometimes asked, whether it is not probable that a boiler may be made too large to furnish a given quantity of steam in a given time, with the greatest economy of fuel, on account of the heat lost by radiation from the exposed surfaces of a boiler of unusually large proportions. In answer to this question we can only state what the total loss of heat is from a boiler of a given size and proportion, under certain circumstances. A test was made by one

of your Committee in March, 1875, to ascertain the loss of heat by radiation from a locomotive when at rest. A freight engine, which stood on a side track near the round house, was selected. The boiler was fifty-one inches in diameter at the smoke box, and of the wagon-top pattern, with one dome. The heating surface in the fire box above the grate was  $97\frac{1}{2}$  square feet and of the tubes 826 feet (internal surface), and the boiler contained 8,500 pounds of water at three guages; there was, however, about two inches more than the three gauges of water in it when the test began. There was no perceptible leakage at the throttle, safety valves, or anywhere about the boiler, which in all its parts was perfectly tight, and was covered with a Russia iron jacket in the usual way. When the test began there was a very light fire on the grate, and the steam pressure was 80 pounds. Steam was maintained at that pressure for twelve hours, during which time the dampers remained closed, and the engine was not moved, no steam was drawn from the boiler, nor was there any additional water put in it, and there was still three gauges at the close of the test. The average temperature of the atmosphere was 50 degrees, with but very little wind. At the expiration of the twelve hours the steam pressure and the fire on the grate, as near as could be determined, were equal to that at the beginning, and the consumption of coal was found to have been 300 pounds, or at the rate of 25 pounds per hour.

This may be considered a very fair test as to the quantity of coal required to furnish heat to replace that lost by radiation, under the circumstances named. In running, particularly when there are high winds, the loss of heat would probably be much greater, even at the temperature given.

Your Committee received the following article on the best manner of Flanging, Annealing, and Working Steel Plates in the Construction of Boilers, from Mr. Wm. Fuller, General Master Mechanic of the Atlantic & Great Western Railway, which though not, strictly speaking, one of the subjects assigned us for investigation yet closely connected therewith. Deeming this paper on that subject one of considerable importance we present it herewith and embody it as part of this report.

R. WELLS, Esq., *Chairman of Committee on Boilers and Boiler Material:*

DEAR SIR—In addition to answering the questions of your circular, I beg to submit the following on the subject of boiler making, as invited by you.

#### FLANGING.

In flanging steel, great care should be taken in the heating of the plates, as there is no doubt more steel destroyed by overheating than by all other causes combined, and as is well known, it is almost impossible to trace to the workmen, the defect of overheating, as of course they will not admit that the defective part is because of their own carelessness. In heating steel for flanging, the orifice of the blast pipe should at all times be covered to the depth of not less than nine inches with *good clean coke*, and not be allowed to burn out hollow under the plate to be flanged, as the blast will strike the plate in large currents, and have a very damaging effect on the steel.

The flanging forge should be long and narrow, as it is very important to have a long heat, so that the plate can be flanged in long sections, as the flanging of short sections is the principal cause of the buckling or warping of the plate, consequently requiring far more use of the sledge, which is steel plate's worst enemy. In turning the flange, it should be worked at nearly the same angle the whole length of the heat, and under no circumstances should the workman attempt to straighten the plate after the color of the heat has left it.

#### LEVELING.

The next step is to level or straighten the plate. This operation is of vital importance in several respects. The plate should be placed in a furnace constructed for that purpose. The furnace should have a strong draft (which can be regulated by the aid of dampers). The fuel used should be well-seasoned bark, charcoal, or soft wood.

The heating of the plate should not be forced, but if it is allowed to heat gradually it will be more uniform; and the process of annealing in the bed prepared should continue with the same uniformity. The operation of leveling the plate should be done with large, heavy, flat-faced wooden mauls. If the plate is thick and stubborn,

large-faced flatters might be used with care, but under no circumstances allow the plate to be struck with the sledge, as it is well known that the face of all sledges is convex, or rounded, and the whole force of the blow is concentrated in a very small point, and is of the nature of a bruise.

The plate, when leveled, and while yet hot, should be placed upon a bed of fine charcoal from four to six inches deep, and covered with the same material four to six inches deep, and allowed to remain in that position from twelve to fifteen hours, according to the thickness, when it will be sufficiently cooled to be handled with ease.

#### RIVET HOLES.

The next operation is the rivet holes in the flanges, which should, in all cases, be drilled. If the flange is *punched* it will be noticed in a few months that cracks will make their appearance, from the rivet holes to the edge of the flange; and, as the flanges of the fire box are generally exposed to the fire, it will be seen that all of the original strength of the steel is required to combat the action of the heat. The rivet holes in the side sheets of fire boxes might be punched, as the edges of the side plates are not exposed to the fire.

#### FITTING.

Care should be taken in the operation of fitting the plates, that the holes are perfectly true. If the holes should overlap, they should be reamed straight and larger rivets put in. The plates should be fitted so that they will lay up close to the flanges without the aid of bolts. Boiler makers, as a rule, place too much dependence upon the use of bolts for drawing and straining, or *forcing* the work together, instead of using their judgment, skill, and common sense in *fitting* the work.

#### RIVETING.

The next step that claims attention is *riveting*. Upon that operation depends, to a great extent, the safety and durability of the boiler. If the work has been properly fitted it does not require much skill on the part of the riveter to make strong and tight work; but, if the plates have not been shaped and fitted in a proper manner, then the riveter, if not a skillful workman, generally completes

the operation of producing a defective boiler. In riveting fire boxes the side sheets should be riveted to the flange of the crown sheet first. The seams down the tube sheet and door sheet should both be riveted down from the crown sheet at the same time, say five or six rivets on each side alternately. By this mode it will be seen that the warping or buckling of the plate is prevented, and whatever strain is produced by the hammering on the rivets and sheets will be carried down equally on each side and worked out at the bottom of the fire box. The use of drift pins for the purpose of enlarging the holes is highly objectionable, and should not be tolerated.

#### CALKING.

Defective calking has much to answer for, and should come in for a large share of close inspection, as it is not easily detected after being finished. If the plates have been well fitted and riveted, the calking should be light. The plate, if chipped to an angle of about forty-five degrees, will not be required to be calked up only about one-third of the thickness. Heavy calking has a tendency to spring and wedge the lap apart, and also to groove the under plate. It also breaks the surface or skin of the plate, and leaves it in the best condition for corrosion to commence its work at once.

The calking tool should not be allowed to touch the inside of the boiler, as corrosion will cut its own channels fast enough without the aid of the calking tool.

#### STAY BOLTS.

The matter of stay bolts should be watched with care, as upon the proper distribution and fastening of them depends a large share of the safety of the boiler. The holes must be exactly opposite each other. The threads on the stay bolts should be cut up full and smooth; threads in the holes full; the tops should be sharp, so as not to *tear* out the thread, but *cut* it. The stay bolts should be screwed into the boiler with a wrench not over twelve inches long, so as to prevent torsion if the bolt should be too large. Neither should the stay bolt be loose. A proper guide is to have the stay bolt fit in the outside plate so that it will not shake in the hole after it has been screwed into the plate three or four threads. The stay bolt should project outside of the plates one-fourth of an

inch, and should be cut off so as to leave a flat surface on the ends.

In riveting stay bolts heavy hammers should never be used, because, if the stay bolt is properly put in, it does not require to be spread out in the center; and that has a tendency to crack the plate from one bolt to the next. The bolts should be driven with the ordinary riveting hammer, and only hammered on the outer rim of the stay bolt.

#### BRACING.

The bracing of a boiler in a proper manner is of the utmost importance, and should be done by the best men in the shop. The braces, from the crown bars to the shell or roof of boiler, should be of sufficient strength to sustain the whole pressure to which the crown sheet is subjected. They should be fitted accurately, so that when the pins are set in they will be tight and firm, but not strained or loaded. Braces that extend from the crown bars up the shell or roof of the boiler should be made so as to admit of being fastened at each end with a pin or bolt, as it will be seen that if one end of the brace is riveted fast to the boiler it is almost impossible to determine if the brace is properly set, after the rivets have been driven in the upper end, in consequence of the rivets holding the brace firm.

The pins that connect the brace with the crow foot and crown bar must be of the same diameter the whole length of bearing on the pin, for if the pin is taper one side of the jaw will have to support all of the load.

#### TUBE SETTING.

The setting and repairing of tubes is, probably, the most expensive item charged to the repair account of the locomotive boiler. The setting or fastening of tubes in the tube sheet appears to be in the same primitive condition it was twenty years since, and the probability is that the question will continue to be a source of expense and annoyance as long as the present system is followed, and unless some plan is perfected whereby a good joint can be easily and rapidly made, so as to prevent the end of the tube from being exposed to the intense heat that is generated in the fire box.

The present method of setting tubes is to allow the end of the



tube to project through the tube sheet about one-eighth of an inch, and then the torture of the tube is commenced by the use of the expanding tool, which is a very severe operation upon both the tube and tube sheet. The effect on the tube is to crush and swell it out, so as to make a tight joint. The nature of the strain on the tube sheet is to burst asunder the small part of metal that is left between the tube holes after the plate is bored; and, after a short time, it shows the nature of the treatment it has received in the operation of expanding—by bulging and cracking between the tube holes.

The question is often asked, Why is it that tubes become leaky and troublesome in so short a time after such an immense mechanical power has been brought to bear upon them? The answer is simple: The whole nature of the material of which the tube is composed has been changed by the enormous strain to which it has been subjected.

#### EXPANSION.

In expanding the tube all mechanics know that stretching and enlarging the tube destroys the fiber of the iron (if iron is used). Next, the tube is subjected to the operation of being hammered over on the end with a round-peened hammer, to form a kind of flange.

#### SMOOTHING.

It is next treated with a calking or beading tool, constructed especially for the purpose of giving it a smooth and uniform appearance, or, in other words, to close up the fractures and cracks that have made their appearance in the operation of expanding and turning over the end of the tube; and it is then in the best possible condition for the fire to complete the total destruction of the end of the tube. Another damaging effect of the expander is the impossibility of its uniform use in expanding tubes, on account of the variations of their thickness, which all mechanics connected with that branch of business are aware of.

In conclusion, I would add, that one great obstacle to the general or successful use of steel in the construction of steam boilers is the lack of skillful and intelligent workmanship.

Respectfully yours,

WM. FULLER,

*General Master Mechanic Atlantic & Great Western R. R.*

## ENLARGED SMOKE BOXES AND STRAIGHT, OPEN STACKS.

To the inquiries made in regard to enlarging the smoke box, raising the exhaust nozzle, and substituting the plain, open stack for the usual diamond stack, we have received but few replies.

Mr. Jas. K. Taylor, Master Mechanic of the Old Colony Railroad, states that the plain stack was used on that road several years ago, without any netting. The exhaust pipes were raised to the top of the smoke box, and a sub-treasury, or spark box, was attached to the bottom for the reception of the sparks, but that the arrangement was abandoned for the reason that it was not proof against the danger of fire along the road. The fuel used was bituminous coal.

Mr. Wm. Woodcock, of the Central Railroad of New Jersey, states that, in the anthracite coal-burning engines on that line, the plain, open stack has been adopted in place of the diamond stack. The exhaust nozzles are on a line with the top row of tubes, or higher, and a cone of wire netting extends from them to the top of the smoke box. This arrangement has worked very well.

Mr. F. M. Wilder, of the Buffalo Division of the Erie Railway, reports that the straight, open stack gives better results, both as to economy in fuel and in the steaming quality of the engine, and that he has enlarged the opening in the top of the diamond stacks with very good results, with engines burning bituminous coal.

In several passenger engines of the Jeffersonville, Madison & Indianapolis Railroad Company, running between Louisville and New Albany, several years ago, the plain, open stack was used, with a modification of what is known as the Smith patent in the smoke box, consisting of a cone of perforated iron, extending from the exhaust nozzles to the base of the stack, surrounded by a case, or lifting pipe. This arrangement answered the purpose so far as draft and steaming was concerned, but small particles of coal and cinders were thrown from the stack to such an extent as to be more or less of an annoyance to passengers in summer, when the car windows were open. After a year's trial this arrangement was removed from the smoke box, and the exhaust pipes raised on a line with the top row of tubes, and wire netting, of  $3\frac{1}{2} \times 3\frac{1}{2}$  meshes per inch, placed across the smoke box above the tubes, and fitting around the exhaust nozzles. A spark box was added to the bottom of the smoke

box with a self closing valve in the bottom. This arrangement has been in use for the past two years with entire satisfaction. The engines steam more freely than before, and all annoyance from dust and cinders from the stack is avoided. The short runs of six miles each give opportunity for emptying the spark box whenever necessary.

The arrangement referred to above, as a modification of the Smith patent, was used on a number of engines on the main line of this road, having smoke boxes of the ordinary size and shape, some three years ago. This arrangement gave good results with the use of Pittsburgh or similar coal, but not with the quality known as Indiana Block coal, except that in the case of both small round particles of coal and cinders were sometimes thrown from the stack in quantities as to be an annoyance. This, however, was principally confined to the use of "Block" coal. When Pittsburgh coal was used the smoke box was comparatively clean of sparks, coal, or cinders; not much of either was thrown from the stack, the draft always being good, and the engines steamed freely; but when the Block coal was used the case was different in several respects.

This coal is composed of thin layers of hard and soft coal alternately; the soft being almost identical with charcoal and very light. These light particles were carried in large quantities to the smoke box by the draft, and were drawn up between the perforated pipe and the "lifting pipe" around it, and closed the perforations by sticking fast in them, to such an extent as to seriously affect the draft on the fire and the steaming of the engine. This was more particularly the case when the engines were worked up nearest their full capacity. As "Pittsburgh" coal was burned going north and Block coal south, this arrangement of straight open stack did not work satisfactorily on the whole, and the fact was demonstrated that an arrangement of smoke stack that gave very good results when one kind of coal was used, did not do so with the other.

After a year's trial the diamond stack was substituted for the arrangement referred to, with better results in every respect in burning the two kinds of coal on alternate trips.

The difference in the results obtained from the use of the same pattern of stack on different roads is, therefore, mainly due to the

difference in the quality or character of the coal used. As an illustration of the difficulties to be overcome in burning the "Block" coal referred to, or coals similar to it, when the straight open stack is used, with an arrangement in the smoke box for retaining the sparks, we give the result of some tests made a few days ago by Mr. Peddle, of the Terre Haute & Indianapolis Railroad, to determine what per cent. of the total weight of the coal put into the fire box was carried through the tubes into the smoke box, under the ordinary conditions of service, by engines having the plain fire box, without a brick arch, water table, or other deflector. Mr. Peddle has several passenger engines in use which have had their smoke boxes extended about thirty inches, the lower part of the extension forming a reservoir extending down as far as the truck of the engine will permit, the bottom being closed by a valve. A plate of sheet iron, immediately above the tubes, extends from the tube sheet to the exhaust pipes, horizontally, and fitting closely around the steam pipes; the nozzle of the exhaust pipes projecting a few inches above it. From the forward edge of this sheet-iron plate a wire netting extends horizontally about thirty inches, then vertically to the top of the smoke box, so that no sparks or cinders could pass out through the stack except such as passed through the meshes of the netting.

The tests were made with two engines hauling passenger trains over the Indianapolis Division. Engine 24 had cylinders  $16 \times 24$  and 5 feet drivers, No. 21 had  $16 \times 22$  cylinders and  $5\frac{1}{2}$  feet drivers; their average weight with tender was 42 tons each, and the average number of cars hauled by each was  $4\frac{1}{2}$ , and the total weight of each engine and its train was 132 tons; distance run by each 146 miles, speed about 30 miles per hour when running. The exhaust was through a single nozzle four inches in diameter. The results in the case of these two engines were so near alike that we give the average of the two.

Coal used in running 292 miles, 11,580 pounds; weight of sparks taken from the reservoir in the smoke box, 1,300 pounds, or nearly  $11\frac{1}{2}$  per cent. of the total weight of the fuel put into the fire box. It was found that a bushel of these sparks as taken out, struck measure, weighed 28 pounds. Three bushels of these sparks were burned on a small grate in a brick furnace in the course of three hours, by a

light blast of air admitted under the grate, to ascertain what proportion of their weight was combustible material. They burned with a heat sufficient to melt the end of a wrought-iron poker in a very short time after putting it in, and after the furnace cooled down the weight of the ashes, cinder, and debris was a fraction less than 12 per cent. of the whole; showing that 88 per cent. of the weight of the material carried through the tubes by the draft was combustible.

The cinders, ashes, and other debris taken from the ash pans of the engines after running the 292 miles, was 928 pounds, or 8 per cent. of the weight of coal used. This added to the weight of the sparks equal  $19\frac{1}{4}$  per cent. of the coal used by the engines, which, so far as generating steam was concerned, served no useful purpose.

With the comparatively light trains hauled, and a four inch exhaust nozzle, it is not probable that the quantity of sparks carried to the smoke box was any greater than usual. Mr. Peddle states it to be about an average, and that on several previous occasions, with trains one-third greater, and fast runs, the weight of sparks taken out of the box was 50 per cent. greater for the same distance run.

From these tests we find that  $11\frac{1}{4}$  per cent. of the weight of coal used in these engines goes through the tubes to the smoke box, and that it is a little more than double the volume there that it was when put into the fire box, or about 25 per cent. of the total volume of coal used. These being the facts, it will be seen that in burning this or similar coal, we must provide store room for one shovelful of sparks for every four shovelfuls of coal put into the fire box, or arrange the smoke stack so that it will be thrown out.

These two engines were supplied with another kind of coal, called "Ashland," from mines in the north-eastern part of the State of Kentucky, and made a mileage of 438 miles with trains of the same weight and speed as in the former trial, with results almost identical with that given. The engines steamed more freely with the Ashland than with Block coal, but the proportion carried to the smoke box was about the same.

We have had no opportunity to test the coking coals used in Ohio and Pennsylvania, but infer the proportion carried to the smoke box from the use of those coals would be considerably less; but we have here the fact demonstrated, in the case of the coals used by Mr. Peddle, that nearly  $9\frac{1}{4}$  per cent. of the total combustible portion of the

coal is wasted by being carried from the fire box by the ordinary draft of the engine working under the conditions given, without being burned, and there is doubtless considerable quantities of very fine particles of unburned coal carried through the netting out into the air in addition to that retained in the smoke box. From our observation we think it probable, on an average, that at least 10 per cent. of the fuel used by engines burning bituminous coal in this country is wasted in the way referred to above. Can this fuel be retained in the fire box until consumed there, giving out its due proportion of heat for useful effect, and how? are questions deserving a solution.

Respectfully submitted,

R. WELLS, <i>Jeffersonville, Madison &amp; Indianapolis Railroad,</i> C. R. PEDDLE, <i>Terre Haute &amp; Indianapolis Railroad,</i> S. J. HAYES, <i>Illinois Central Railroad,</i> S. M. CUMMINGS, <i>Pittsburgh, Ft. Wayne &amp; Chicago Railway,</i> L. S. YOUNG, <i>Cleveland, Columbus, Cin'ti &amp; Indianapolis R.R.</i>	} Committee.
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On motion of Mr. Wilder, a recess of five minutes was ordered.

Upon re-assembling the report was received.

Mr. COOLIDGE, Fitchburg Railroad—I move that the thanks of this Convention be tendered to the Committee for the completeness of their report.

The motion was carried unanimously.

### Discussion on Boilers and Boiler Material.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—In justice to the Committee, I believe it necessary to state that I think, and I believe the other members of the Committee agree with me, that we had too much work cut out for us. We had four or five different subjects, and all coming into one report, making an exceedingly long one, and if you attempt to cut it off it is difficult to say just where you may do so. It is tiresome to listen to so long a report, but when the subjects are referred to the Committee we feel in duty bound to do the best we can, and although it is somewhat long and tiresome, I hope the members will bear in mind that we could not make it much shorter.

Mr. CHAPMAN, Cleveland & Pittsburgh Railroad—I move that a committee of three be appointed before we adjourn to draw up suitable resolutions, expressing the sense of this Association in regard to the death of one of our members, Mr. Pierce. He died soon after our meeting in New York.

Mr. SETCHEL, Little Miami Railroad—I would second that motion.

THE PRESIDENT—You have heard the motion, that a committee of three

be appointed to draft resolutions concerning the death of Mr. Pierce. He was a member of this Association quite a number of years, and was present at our last meeting. He died soon after very suddenly.

The motion was carried, and the President appointed as such committee Messrs. Chapman, Wells, and Garfield.

**THE PRESIDENT**—We have some ten minutes before the time of adjourning. There will be hardly time to commence the discussion of the report just read. Is there any business to come before the Convention? There has been no committee appointed to select the next place of meeting. A motion to appoint such a committee is in order.

On motion of Morris Sellers, the President was authorized to appoint such committee.

**THE PRESIDENT**—I will appoint Messrs. Graham, Thompson, and Sedgley.

The Convention then adjourned until 9 o'clock, Wednesday morning.

## SECOND DAY'S PROCEEDINGS.

WEDNESDAY, May 17th, 9 A. M.

President Britton in the chair.

**THE PRESIDENT**—Is the Committee on Resolutions relative to the death of Mr. Pierce ready to report?

Mr. Setchel read the report of the committee.

### Resolutions on the Death of E. Pierce.

*To the American Railway Master Mechanics' Association :*

**WHEREAS**, It has pleased Divine Providence to remove from us our friend and fellow-member, Mr. Eldridge Pierce, by death, therefore be it

*Resolved*, That in his decease we have lost a valued friend, society a useful and honorable citizen, and this Association one of its most intelligent and useful members.

*Resolved*, That we tender to his bereaved family our heartfelt sympathy in this their great bereavement, and that we pray and trust that Providence, who rules over all the affairs of men, numbering our days, will kindly and tenderly care for them in this seemingly mysterious dispensation ; and, be it further

*Resolved*, That a copy of these resolutions be forwarded to the family of the deceased, and that they also be inserted in the proceedings of this our annual meeting.

N. E. CHAPMAN, }  
R. WELLS, } *Committee.*  
E. GARFIELD, }

On motion, the resolution was adopted.

**THE PRESIDENT**—The next business in order is the discussion on "The Best Material, Form, and Proportion of Locomotive Boilers and Fire Boxes." The report has been read and the subject is now open for discussion.

**Mr. WOODCOCK**, Central Railroad of New Jersey—I feel very much interested in this subject, as a very large percentage of our troubles come from the failure of fire box sheets. The difficulty we all know, and the question is, How shall we arrive at a remedy? This has been suggested by the report read, but we are not all prepared to indorse the report as to the cause of these failures, and may not agree as to the remedy. Our superintendents come into the shop, and, like good managers, they desire to impress upon our minds that there should be a rigid economy in locomotive repairs, and we at once refer them to the cost of repairs of fire box sheets as a very great source of the expense. It should be the object of associations of this character to furnish some remedy for this defect. Now, can we give any information toward solving this problem? Engines in the same service, built of the same material, and run under the same circumstances will not wear alike. One will run a much longer time than another. I have an instance of that kind in mind. I refer to two engines both placed on the road at the same time, one of which has been taken into the shop during the past week. It has made a total mileage of 254,000 miles, while the other engine, one of the same class, has had, during the same time, two new furnaces. The first made only 95,000 miles, and the next 117,000 miles. The furnaces were made of the same steel and put to the same work—both engines being in service about seven years. Now, in taking out one of the side sheets of the first engine, I found ten cracks, varying in length from one to ten inches. I have a small piece cut out of one of these sheets, showing the crack going directly vertical and straight, starting from a stay bolt, as was described yesterday. To all appearances, when you come to test that you will find it as tough as any material you can get hold of. I call your attention to another engine which had run 106,000 miles, when it was found necessary to remove the furnace. In order to test some items about steel hardening I had some pieces taken out of these sheets. I tried to bend it, just as it came from the fire box, and found that it would not bend, but would break like a piece of cast iron. I heated it red hot, and could then bend it down flat, showing that if we could arrive at some plan



to anneal the sheets in the fire box, that it might restore them to their natural condition. Some change certainly takes place by heating. In the first attempt to work these samples it shows they are like pieces of cast iron, but after annealing they can be bent into any position. The question is, Can we bring steel into that state after using it three years? I feel, if it could be done, that it would in some degree prevent the cracking. In reference to the highest mileage made, I may remark that we have engines which have run over 200,000 miles and are apparently as good for service as ever. That is one of the difficulties I can not understand. The sheets on these engines are in perfect order and in good shape, while other engines running on the same train, or opposite trains, made out of the same material and by the same workmen, will not make over 100,000 miles without coming into the shop for repairs. That is one of the things a superintendent can not understand sometimes. In regard to the thickness of the sheets, I believe there is something in that. In the freight service some engines on our road have made 108,000 miles with steel sheets a quarter of an inch in thickness, and we have had but one of these to fail, and that has a crack twenty-three inches long. We seem to get better results from a quarter of an inch thickness, and we have changed our sizes and are now making them all a quarter of an inch thick. We have some five-sixteenth inch, but most of these have cracked; and we have come to the conclusion that a quarter of an inch is the best thickness. In regard to corrugation, I was so much impressed with the advantages to be derived from it that we have begun to test that matter, and I hope in a short time that we will be able to give you some facts in reference to the working of corrugated sheets. From what I have already observed I have reason to believe we will be able to report good results.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—I hope the members will criticise any of the theories advanced by the Committee, or statements they may make, and by so doing we may get at the truth in regard to the sheets becoming hard after being used. And while I think that will be found to be the case with almost any kind of steel or iron; the reason, probably, is on account of these strains that we speak of in our report. By straining the sheet in different directions the tendency is to harden the metal. I suppose we are all familiar with the fact that, if we take a piece of iron and undertake to bend it, and exceed the elastic limits at the point of bending, it will become harder at that point than at any other, and if you try to bend it back it will bend in a different place. That is the reason these sheets gradually become hardened. If you anneal them they go back to their original toughness. I think these strains, brought upon the sheet exceeding their elastic limit, are what produce the hardness in them.

Mr. ROBINSON, of Canada—Mr. Woodcock speaks of ascertaining the true cause and finding the remedy for the cracking of fire box sheets. This is

the great bugbear in the minds of Master Mechanics. I think myself there are a large number of Master Mechanics on the right track to overcome the difficulty. If we go back to first principles, we will find out that the first cause lies in the material as the starting point. The more nearly we can get material like copper, the more nearly we will arrive at a proper material to avoid fractures. Iron gives way, and steel gives way, and steel undergoes a change in using it in the fire box. I have come to the conclusion that steel wants to be made a homogeneous metal. The meaning of the term homogeneous steel is an iron that is perfectly equal throughout, not fibrous, or fibers running in all directions, but it should be equal throughout, or homogeneous and of the same nature, so that there should be no more strength in one direction than in the other, and of so low a grade that it is but very little removed from iron. Many steel makers are learning that the more nearly they approach that, the more nearly they approach a metal like copper. Of course, it is impossible to make steel or iron as ductile as copper. The next advantage, no doubt, lies in the mechanical arrangement of the metals. For that reason I look forward with great interest to see this subject followed up—to know the results of using corrugated sheets. I am very much pleased with what little experience we already have on that subject. Before I sit down I would like to ask the Committee whether they are able to determine the advantages of a deep or shallow fire box for bituminous coal. I have been asked why the long fire boxes for anthracite are not good for bituminous. The Committee recommends a large fire box for bituminous. I presume they mean a fire box not so much wide as long, so that the gases escaping from bituminous coal shall have room to combine together, and combustion take place perfectly. It would be very interesting to know how far the anthracite boiler is adapted to burn bituminous coal. It would be very convenient to adopt either coal according to the state of the market. I think it would be a very interesting question to take up at our next meeting, and if the Committee could answer now it would be very much better.

Mr. HUDSON, Rogers Locomotive Works—I have listened with a great deal of interest to the report of the Committee on Boilers and Steel Plates, and I must say that I agree entirely with them as to the cause of the cracking of steel plates, but I am not satisfied with the recommendation of the Committee to use the lowest grades of steel, or those approaching iron. I am not satisfied that that is the best material for furnaces. While I consider that it is the best material for the outside shell, I have serious doubts about its being the best for furnaces, and my reason is this: It is a well known fact that the lower the grade of steel, the more it contracts in cooling from a given temperature. If you have a large piece of steel to harden, in order to prevent its cracking when you cool it, you must enrich the outside with carbon to a greater extent than the inside. It being a fact that the higher the amount of carbon, the less the expansion in heating, and the less the contraction in cooling, it looks as though a material containing a large amount of carbon

would better adapted for furnace plates than this extreme low grade. But there are other conditions affecting the quality of the plates, and I apprehend we must look to the quality of the plates for the difference in their endurance. Mr. Woodcock says: why is it that the steel of one maker and one furnace will last two or three times as long as it does in another furnace. I apprehend that the difference will be found in the difference of composition of the metal itself. You speak of the homogeneous metal as being of uniform composition. It is far from being that. Steel makers know it is extremely difficult to get their steel of uniform quality all the time. It is one of the difficulties, and in reading some papers on the subject of steel recently, I find that that the composition of this metal for furnaces is very uncertain. Some say it ought to contain  $\frac{1}{100}$  of one per cent. of carbon, others that it ought to contain twenty or twenty-three or more. Some say you may have considerable phosphorus, and some say you can have sulphur. You may have magnesia, and you may have silica, but the proportions of these are different with different makers, and different with the same maker. I would suggest that samples of all sheets be kept, and when sheets fail, a piece be taken from that sheet and the two be then tested—that is, brought to the same ultimate analysis—and a record kept. In that manner, after a time, we shall arrive at a knowledge of the best possible material for steel furnaces. But unless we do that, I apprehend we are working somewhat in the dark. The differences are more in the quality of the plates than in the working of them. While I have no doubt of the beneficial effects of corrugating, still corrugating only mitigates the difficulty, it does not entirely remove it. As Mr. Robinson says, if we had a material as elastic as copper, that would go and come, we would have just what we want. I apprehend that in looking for such steel in the low grades, we are looking in the wrong direction. I am afraid so. Again, as regards the form of the furnaces. It is undoubtedly a good recommendation—I think the Committee recommended it—that the furnaces should stand inward from the top, if possible, in order that the particles of steam shall rise perpendicularly, and come to the surface of the water. In that way the heat would be carried off without endangering the plates. Of course, no form of plates nor quality of material will guard against the evil effects of accumulations of scale, because scale is almost a non conductor, and where it is allowed to accumulate, the material is likely to give out.

Mr. COOPER, Indianapolis, Bloomington & Western Railroad—I think the greatest trouble with the fire box is that the steel plates are too thick. The first engine put on the Chicago, Burlington & Quincy Road, I think it was in 1865, had quarter inch steel plates, and they have always put in that thickness from that time, and when I was on the Kansas City Road I put in quarter inch steel there, and never had any fire boxes crack with it. There was one engine on the Hannibal & St. Jo. Road, put on in 1869, which had quarter inch steel plates. The water is very bad there, but the engine is as good to-day as it ever was, as good as the day it was put in. On the road I am connected with now I have put on thirteen patches during the past year with five-six-

teenths inch steel. I used to think that steel was just the thing for fire boxes, but I have almost changed my mind; but I have during the past year put in three quarter inch steel fire boxes, and they seem to be doing first rate; I think they are better than five-sixteenth inch, and I think Mr. Woodcock's experiment will prove it.

Mr. WOODCOCK, Central Railroad of New Jersey—I would state with reference to Mr. Hudson's suggestions of selecting a sample piece from each sheet, that I think we took some action upon that at the last Convention, at least I acted upon that, and from all the new sheets we have put in recently I have cut out a piece of steel and marked it. These we hold for tests in case we want to make a test of any sheets that crack. There are always pieces that are sheared off that can be retained at no expense.

Mr. HUDSON, Rogers Locomotive Works—I wish to impress the importance of the testing of these pieces, to the ultimate analysis, to ascertain the precise amounts of sulphur, etc., in order that we may arrive at a knowledge of the material that gives the best possible result in practice. I apprehend that is what we all want to get at.

Mr. CLARKE, Northern Railroad of Canada—I think the great trouble with the steel makers is, that they are going it blind as to the proportion of soda, sulphur, etc.; I think there is no doubt in a very short time that they will be able to come to a definite conclusion as to the proper proportions, and then we can get sheets fitted for different classes of work—for fire boxes, boilers, etc. At present I think it is more chance than anything else that we get sheets of uniform grade; but I know Park Brothers, of Pittsburgh, have supplied the Grand Trunk Railroad with steel for some twenty-five engines, and so far none of them have cracked.

Mr. BARRETT, Grand Trunk Railroad of Canada—We have ninety engines with steel fire boxes. We find that twenty-five of the whole number are with black diamond steel made by Park Brothers. These twenty-five engines have been running side by side with engines that have given us a great deal of trouble. We have twenty engines with cracked sheets, and in no case has the black diamond given us any trouble. These twenty engines have been running where the worst water is; none of them have been running over two years, and none of the Park engines have run over two years and two months. If any of you know of the peculiarities of the manufacture of this steel I would like to know it; it is five-sixteenths of an inch thick. We have no quarter inch, but have been patching with steel of a quarter inch and the patches are very satisfactory indeed. One other trouble is the bulging between the stays; we have thirty or forty such cases, and many of the cracked sheets had bulged between the stays.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—In reference to the thickness of the sheets, the reports made by the Committee show that there are about twenty sheets cracked which are a quarter of an inch thick; all the others were five-sixteenths of an inch thick. Of these twenty

I think fifteen or sixteen were on the Pittsburgh, Fort Wayne & Chicago Railroad (Western Division), and three or four on the Illinois Central; these are the only roads reporting quarter inch plates cracked.

Mr. HUDSON, Rogers Locomotive Works—In regard to bulging, I have no knowledge of steel sheets bulging except where overheated from accumulations of scale or some such cause. In regard to the different compositions of steel, I understand that of Park Brothers has a higher percentage of carbon than many of the other steels made in Pittsburgh. It is a fact that the steel makers keep their proportions to themselves generally, and hence the importance that we should arrive at a knowledge of what the sheets ought to be in order to know when we get the right quality. It is a fact that the steel makers in Sheffield conduct their business on the same general plan, and the same materials are used, and two establishments, one across the street from the other, nominally use the same materials and in the same proportions, yet one makes a good reliable article and the other a poor one, and so it is here. I apprehend that the differences we find in the steel plates are on account of the difference in the composition of the metals. It certainly is a fact that steel plates being so far from what they ought to be are very uncertain.

Mr. COOLIDGE, Fitchburg Railroad—It seems to me this matter in regard to steel sheets, although the discussion is very interesting, has resolved itself into a more simple matter than it is generally considered to be. Any one who has listened to the reading of the report, and has also listened to this discussion, must have observed this fact, that in the West, where the water is bad, that the percentage of the fractured and ruptured sheets is in some cases as high as thirteen per cent., while in the East, where the water is purer, the percentage is very small. If I understood right, out of two hundred on the Boston & Albany Railroad there has been but one instance of a cracked sheet. So it seems to me this matter is much more simple than it appears to most of our members. I judge from the report of the Committee that they recommend the use of steel a quarter of an inch in thickness, instead of five-sixteenths, at least I understood it so. Now they have arrived at that conclusion from hearing from quite a number of different roads, and the testimony of the members given since then, in this discussion, tends to the same conclusions. On the other hand, it seems to me that where the water is pure there is very little trouble with steel sheets, and I think it would be almost the universal testimony that the worst results we have ever had from the use of steel are better than we have ever had with iron, although I must confess the evidence is limited to the members present. In conclusion, I would simply say this, we are in the hands of the manufacturers; I do not know whether there are any here present, but I think it would be very interesting to hear from them. I think that with the best they can give us, and the best they have given us, we are much better off than we have ever been in the use of iron or ever can be.

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—I listened to the reading of the report yesterday with a great deal of interest. The road

I represent have adopted steel for boilers, and, I think, with marked success; but, instead of laying the troubles with our boilers to the manufacturers of steel, I take it home to myself, in a large degree. I may state my opinion in regard to the qualities and the different makes of steel, for we have used all kinds that I know of—Bessemer, homogeneous, and crucible;

I could instance a case where we put twenty locomotives on our road in 1874, when our line was crowded with business (and I presume the first engines made from thirty to forty thousand miles each), that have been in constant service up to the present time, and but two or three have been changed, and they were of the crucible steel. That lot of engines has given us the best results of any steel we have ever had on the road. Since Bessemer's steel has come into use we have used it very largely, but I have occasion to doubt whether we shall get that service that we get from the crucible steel, although we have not had it in use long enough to speak from personal knowledge. I think we may have to go back to crucible steel for our furnaces. There was one thing in regard to the report which I wish the Committee had enlightened us upon, and that is the degree of heat required to make a sheet contract. I have made some experiments recently. I do not believe you can contract that sheet in the center at the temperature we run steam at in our locomotives with one hundred and twenty to one hundred and forty pounds pressure. We have put gauge cocks in the side of our furnaces. We find that within three-eighths of an inch of the inside of the sheet we get water when the engine is not working; when the engine is running we get almost pure steam. Withdraw the gauge cock three-quarters of an inch and we get one-third water; withdraw it an inch and we get one-half; withdraw it further than that and we get solid water. I am fully convinced that we are driving the water from that inside sheet and exposing it to the heat of the fire. I do not believe the trouble is in the metal. I have given it the severest test, by doubling it without even heating it, and find the material almost as good as when put into the boilers; I think there is the great secret of fracturing the sheet. I do not think that doubling will have any perceptible effect on the sheet under five hundred degrees. I wish the Committee had told us why the sheet should contract at that point and not elsewhere. I think, instead of our complaining of the makers, we had better look at home and see if we are not at fault. When you talk about a quarter inch sheet, and I see the liability and almost certainty of forcing the water away from that sheet, I dare not risk it. I do not know the experience of other gentlemen, but I must say, if that sheet comes red hot I dare not risk it a quarter of an inch thick. I would be glad to hear from the Committee in regard to the experiments they have made to show why the sheet should contract at that point and not elsewhere. If indeed we do not get it above the temperature at which we run steam. When steam is one hundred and forty pounds pressure we should not touch five hundred degrees of heat; and I think that the sheet would not contract

permanently at that temperature. I would like to see the experiment on a sheet heated to five hundred degrees. I think, instead of complaining of the manufacturers, we should give them a great deal of credit for the material they are giving us to-day for boilers. I think, probably, the trouble is with ourselves. I do not say a four-inch waterspace would help us. I think you would force the water away from a four-inch waterspace as well as a three-inch. It is a question to which we have all given a great deal of thought. It has given me a great deal of trouble, and my only hope, at the present time, is in corrugating our plates. It is a very simple method, and inexpensive. I presume, to corrugate the side sheets of a furnace would not add more than five or ten dollars to its cost; and, with engines that have made 30,000 miles with these plates, they are apparently as smooth and in as good condition as ever. I have good reason to hope that we have solved the problem of how to avoid cracked sheets. The next question is how to keep a solid body of water against that inside plate under the excessive heat to which it is subjected. By careful observation I have become convinced that we concentrate the heat against the back end of the arch to a fearful extent; and it is there that our furnaces crack invariably. We have suffered so much I was induced to introduce a gauge cock to ascertain the condition of the water at that point. I have not made the experiments thoroughly yet, but I simply wished to ascertain directly, for that is the point where we suffer so much. I do not believe it is possible to use iron of poor grade, for we get steel that works more like copper than any thing else, and it fails; and I have said to myself that the trouble is not with the material, for I take it from a sheet that has ruptured and double it over and straighten it out, and it is as soft as when it was put in. I think we have upset it with too high a degree of heat, and when the boiler has been allowed to cool off then we have had the fracture. We have not had a sheet to break when the water was even warm—it has always been when the engine has stood in the house from twelve to forty-eight hours. I hope to hear a free expression, if any member has made any test, why a sheet should contract at that point and not elsewhere. If the water lay against that side of the sheet there is no reason why the heat should be greater at that point than above or below. I have come to the conclusion that that degree of heat, with steam at one hundred and forty pounds pressure, will not hurt a plate.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad.—I do not know whether I can explain the opinions of the Committee as to why that sheet should contract, but it is my opinion that the difficulty is as he states it. The heat is so intense at the point near or opposite the fire that the formation of the globules of steam along that part of the sheet necessarily drives away a portion of the water; and when the water is not in contact with the sheet it will become much higher in temperature than the water at other points. The temperature of the sheet at that particular point would

not injure the metal or contract it, provided all other parts of the sheet were of the same temperature; but, as they are not, this highly-heated portion will expand in proportion to its temperature; but as the sheet around it will not permit that expansion, therefore the metal in that heated part must upset, if that is beyond the elastic limit. If sufficiently elastic to give within itself no injury will result, but if it is not sufficiently elastic it will then, to a certain extent, be upset; and when the whole sheet becomes of one temperature this part will be under a tensile strain to that extent. That is why the portion, in the sheet referred to, will become too short; it is not the heat it is subjected to, but simply because it has expanded beyond the elastic limit and has upset and thickened. I think the difficulty is not originally in the material but in the work we require of it. We require it to stand this upsetting, and, of course, if it is upset there are times when it is of the same temperature over the whole sheet, when it must be under a strain in the opposite direction. Now, from experiments which have been tried some years ago on the elasticity of steel, by Faraday and others, it was found that steel would not resist as much tensile strain when tried once by compression and next by elongation. The change in direction seems to have a deleterious effect on the metal. The low grade steel, referred to by the Committee, we, of course, mean is a steel that is sufficiently pliable to work without danger of cracking. It is not in our minds whether the open-hearth steel or crucible steel is best. We do not know certainly which is the best for fire boxes. We do know that the largest number of sheets in use, giving a very high mileage, were of crucible steel; we also know that quite a number of sheets reported were of the open-hearth process; whatever the quality or character of the plates they were made by that process.

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—Our friend from the Grand Trunk spoke of sheets bulging between the stays. I would like to ask him what his theory is; on what grounds he accounted for it; whether it was on account of too high pressure in the boiler, whether it was filled up with mud, or the water was driven out so that the sheet became soft, for we all know that a plate of iron, heated, will not stand the same pressure that it will stand when cold. I infer there is some cause for it. If it is on one spot, I look for mud; if I do not find it, I infer that the water has been driven away. I simply make these remarks to see if any other gentleman has been led to the same line of thought, that we are driving the water away from that sheet to a fearful extent beyond what we estimated. Mr. Wells' explanation is not quite clear enough. He did not tell me whether he believed the difficulty was caused by driving the water away from that particular point of the sheet, and that, therefore, the sheet arrived at a higher temperature than any other point in the furnace.

Mr. BARRETT, Grand Trunk Railroad—I can not supply any theory for the bulging. The back sheet never bulged. The front one, just below the fire-brick arch, bulges slightly. The side sheets bulge for about the depth of



twenty inches above the foundation ring, almost the whole length of the side sheet.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—The opinion of the Committee is that the intense heat there drives the water away, and on that account that portion of the sheet is more highly heated than as if the water were in contact with it. This expansion, therefore, occurs, and that being on the cooler portion of the sheet upsets it, and, therefore, when it becomes cold, it results in this tensile strain which produces the injury.

Mr. ROBINSON, of Canada—I would not like the public of Philadelphia to imagine that the Master Mechanics are grumbling about the steel for fire boxes. We are glad that steel has been made suitable for fire boxes, because if we take the percentage of failures in steel fire boxes they are very small. On the road I was lately connected with, they have nearly one hundred engines with steel fire boxes, and they have no more trouble than they formerly had with copper fire boxes. The dirtier the water the more trouble you will have. The same with copper. This is perfectly true. I, for one, do not grumble at the quality of the steel we are getting, but whatever we are getting we can have the satisfaction of grumbling. We shall go on wanting something better until we die. I, therefore, make these remarks in case it may be thought we have discovered some new species of grumbling. The experience we are getting is admirably adapted to overcome these difficulties we are now complaining of.

Mr. WOODCOCK, Central Railroad of New Jersey—We ought to criticise the steel makers. If we arrive at the conclusion that steel is perfect, the steel makers will stop trying to better it. I believe we ought to improve on it, and endeavor to remedy its defects to the fullest extent. We are getting good results, and I would not want to go back to iron sheets. Still, I think we ought to criticise them and bring them out.

Mr. HUDSON, Rogers Locomotive Works—In my remarks about insuring the quality of steel, I did not wish to blame the makers. I have no doubt they are doing the best they can; but still it is a fact we have no certain knowledge as to the quality. The fact is this: we want to look for a better quality, or an improvement in quality. In my remarks, made a year ago, I think, on this subject, I said we must get a better material that will stand all these strains. We must get also a better circulation. Now, I apprehend that that better circulation might do something—perhaps a good deal—toward remedying this evil of cracking plates. How shall we get it? If we do not set up a mechanical circulation, I am not prepared to say how. I know if it was done it would remove the difficulty of cracking plates. It has been asked why deep furnaces are more likely to crack than shallow ones? I apprehend that the cause is in the better circulation of water in these fire boxes than in the deep ones. The particles of steam have a better opportunity to get to the top than where the furnace is twice the depth. My own

opinion of the proportion of waterspaces is that we must increase them if we would prevent this evil. In place of making them three inches, we must make them three and a quarter or four inches at the top. Instead of three and a half, we must have five inches, or in the absence of that we must set up some method of securing a mechanical circulation that will prevent this difficulty. Now, as Mr. Sedgley says: How is it that steel plates can be overheated in contact with steam? I have known of boilers where the heat was communicated through the steam, some portions of the boiler were not in contact with the water, and the whole upper portion of the boiler became so hot that it would set fire to the wood work. I have seen locomotive boilers in that state. The steam was superheated. It is possible to superheat the steam in the side of the furnace. It is very certain that the heat is very much above the temperature due to steam.

The Convention then took a recess of ten minutes.

**THE PRESIDENT**—I have the pleasure of introducing to you Mr. Briggs, of the Franklin Institute, who will, by request of a number of the members, deliver you a short lecture on the Circulation of Water in Steam Boilers.

#### **Circulation of Water in Steam Boilers.**

**Mr. Briggs said:**

**MR. PRESIDENT AND GENTLEMEN**—I am much gratified by the honor conferred upon me in being requested to address you upon the subject of the phenomena attending the ebullition of water, and with the risk that I may be reciting facts well known to all, and certainty that what I shall say will be merely elementary, I venture to quote a portion of a lecture delivered by me before the Franklin Institute, trusting that a new view of old facts may not be out of place.

The three forms of matter—solid, liquid, and gaseous—are incident to some definite quantity of heat which accompanies each form, which is known as the latent heat, and varies in amount for the different substances. For water, which is the substance under consideration at this time, the latent heat added to and absorbed in the change of form from ice at 32° to water at the same temperature is 142°.65 (Person), and in the change of form from water to steam of 32° is 1,092° (Regnault). But the sensible temperature of a liquid at which it will vaporize is found to vary with the pressure (or tension) of the vapor above it, and the tension of steam at 32° is only 0.085 pounds per square inch, while the pressure of the atmosphere is 14.7 pounds per square inch. Ebullition or free boiling of water

does not take place under atmospheric pressure until the water is heated up to  $212^{\circ}$ , at which point the tension of steam is equal to the usual atmospheric pressure of 1.47 pounds per square inch, and the latent heat of change of form from water at  $212^{\circ}$  to steam at the same temperature, is  $966^{\circ}$  (Regnault).

The other properties of water, as regards heat, with which we have to do in considering the circulation in a boiler, are its expansion and its rate of conductivity. Water expands (on being heated) at anomalous rates: about 0.8 per cent. from  $40^{\circ}$  to  $100^{\circ}$ , about 3.9 per cent. from  $40^{\circ}$  to  $200^{\circ}$ , about 8.7 per cent. from  $40^{\circ}$  to  $300^{\circ}$ , and about 11.5 per cent. from  $40^{\circ}$  to  $350^{\circ}$ . The conductivity of water is exceedingly slow (as it is in all liquids when not in motion), so slow that it can be assumed to be absolutely non-conducting in the present inquiry. As a consequence of this non-conductivity of water, it can only be heated by the application of heat below, and by transfer and diffusion of the state of heat by means of the motion of the particles of the fluid mass; and uniformity of temperature is attained in such a mass only by continual circulation.

The usual and accepted method of heating water, therefore, is by placing it in a vessel, to the under side of which heat is applied, which heat is transferred through the material of the vessel and imparted to the water. The film of water in contact with the inner surface of the vessel, at the place where its outer surface is exposed to the fire, becomes heated and expands and mixes with the water immediately near it, until a stratum of water is formed which is lighter than the mass of water above it and tends to float, and its flow being supplied instantly by heavier water, a circulation is commenced. After the establishment of a circulation of slow velocity, acceleration goes on, until, at some rate of movement, the friction of the currents of water against the sides of the vessel or against themselves (for eddies, whirlpools, and cross-currents will form in a vessel under such circumstances) offers a resistance to greater velocity, exactly equal in amount to the disturbing force of the expanded water in trying to rise. The slow run of first movement with gradual increase of velocity and circulation arises from the fact that particles of water are, in common with those of other bodies, either solid, liquid, or gaseous, subject to the laws of the application of force; whereby they do not commence to move until some resistance is over-

come, nor do they cease to move until they acquired momentum is compensated. So long as the heat imparted to the water is below the boiling point, a circulation of hot water can be urged with perfect quietness in properly formed vessels, and in tubes, until an equilibrium of temperature of the water in the vessel, or tube, is established; and when the heat of the water is abstracted in the course of circulation, a high velocity of current can be attained, and great quantities of heat can be transferred without disturbance of flow.

But as the boiling point approaches, another train of conditions is brought to bear, which may be better considered by referring to the accompanying figure.

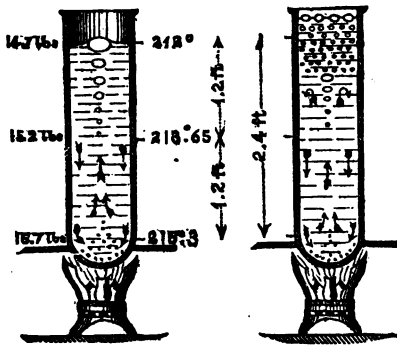


Fig. 1.

Fig. 2.

Fig. 1 represents a vessel containing water exposed to the action of a fire upon or under the bottom of a vessel. It is supposed that the depth of water in the vessel is 2.4 feet, when it would follow, as the weight of a cubic foot of water at  $212^{\circ}$  is very nearly 60 pounds, that the pressure of the column of water at the bottom of the vessel is very nearly one pound to per square

inch. The relations of pressures and of temperatures of ebullition, in this column of water are: at the surface there will be the pressure of the atmosphere = 14.7 pounds, with its corresponding temperature of ebullition =  $212^{\circ}$ ; at the depth of 1.2 feet the pressure will be 15.2 pounds, and the temperature of ebullition =  $213^{\circ}.65$ ; and at the bottom, at the depth of 2.4 feet, the pressure will be 15.7 pounds, and the temperature of ebullition  $215^{\circ}.3$ .

The effect of the application of fire to the bottom of this vessel having first been admitted to raise the temperature of the entire mass of water to  $212^{\circ}$ , and having expelled most of the air which was absorbed in the water at its normal temperature before heating, will next be extended to the formation of steam as the means of dispersing the constant addition of heat; and somewhere in the height

of the column, a point will be reached, where the rate of circulation will permit the return water from the top surface, which will inevitably have the temperature of  $212^{\circ}$ , to reach the bottom where it will be heated, let us say, to  $213^{\circ}.65$  by the fire.

The specific heat of water compared to that of iron is very great (about nine times as great), and a film of water of the same thickness as a sheet of iron, with which it may be in contact, has a little the greater capacity for heat; but the rapidity of convection of heat in water is far greater than that of the conduction in iron, so the general temperature of the water in contact with the iron is maintained with the smallest excess of temperature of the iron.

The extreme tenuity of the gases of combustion, although they have about twice the specific heat of the iron by weight, reduces the relative quantity of heat, by volume, in contact with the bottom of the boiler to such an extent that the external temperature of the iron where exposed to the fire, may, for ordinary practice, be taken as that of the water within the boiler. Still, notwithstanding the great rapidity of convection, the first result from the intense heat of a flame is to create numerous exceedingly small vesicles of steam (represented by dots on Fig. 1) in contact with the internal surface, which floats away from it, and in a short distance are absorbed into the water again, giving out their heat to the water of lower temperature. With active firing these small vesicles will form a turbid cloud, and the closing up of the vesicles, and contact of water with the bottom, will produce a characteristic singing noise which attends boiling, and is particularly noticeable just before the boiling point is reached, when the water at the bottom may be a little above  $212^{\circ}$ , while that of the mass above may not have attained that temperature. In the case which has been supposed, where the temperature of the ascending current is to be  $213^{\circ}.65$ , after this cloud of vesicles is absorbed, which will occur within two or three inches of the bottom, the water will become solid again, and rise to the height of 1.2 feet before the pressure upon it will have become sufficiently reduced to allow a bubble of steam to form.

At this height evaporation should commence; it will, however, not do so, because the heat is completely disseminated in the water, and because water has considerable adhesive force or strength of itself (although the particles move upon or slide over each other with

much ease, they offer a positive resistance to being separated, which, by the laws of thermodynamics, is measured by the latent heat absorbed), and the water will hold together even when agitated by currents and eddies, as shown in Fig. 1, until relieved of 1 to 2-10ths of a foot more of column pressure; it then begins to exhibit, first a turbidity of small vesicles of steam intermingled with the water, which, ascending with the current and agitated together, will, by joining, form small bubbles of steam. These bubbles will have their internal atmosphere of steam, and their internal surfaces are free to give out steam to this little atmosphere, and these little bubbles, which began to form under about 15 pounds pressure, will augment in size as the pressure is relieved, at the same time that they are growing from the formation of steam from the water surrounding them until this formation of steam will have reduced the temperature of the surrounding water to  $212^{\circ}$ , when the bubbles, and the water enclosing them, will have reached the surface.

Thus, while the circulation was produced by the levity of the column (the heated water), it is greatly promoted and accelerated by the presence of steam in bubbles in the heated mass, and the value of this agency of bubbles can be estimated as follows: A pound of water at  $212^{\circ}$  is very nearly 28.8 cubic inches or 1-60th of a cubic foot, while a pound of steam at the same temperature is 26.36 cubic feet in volume, or 1,580 times as large as the water from which it was made. The case supposed in Fig. 1 gives  $1^{\circ}.65$  of heat as being expended in making steam from what was solid water at the depth of 1.2 feet of  $213^{\circ}.65$  temperature. The latent heat of steam at  $212^{\circ}$  is  $966^{\circ}$ , and consequently the  $1^{\circ}.65$  will make (when applied to a pound of water) 1-580th of a pound of steam, the volume of which will be 26.36-580ths of a cubic foot, or 1,580-580ths = 2.7 times the volume of a pound of water; and the mixed volume of bubbles of steam and water which will come to the surface at the temperature of  $212^{\circ}$  will be very nearly 3.7 times as great as the volume of water which was solid at  $213^{\circ}.65$ , lower down in the vessel, and the entire volume of mixed steam and water, above the point of the first formation of steam, will be 2.35 times that of the original water at  $213^{\circ}.65$ .

Perhaps it may be well to exhibit some rate of evaporation in conjunction with the supposed ebullition, and this can be done by com-

parison with the ordinary rate of firing of a stationary boiler, which is from 10 to 12 pounds of coal per square foot of grate per hour; and as each pound of imperfectly consumed coal on such a grate yields 9,000 to 10,000 units of heat only, the total efficiency of a square foot of grate becomes 100,000 to 108,000 units of heat per hour, equal to about 30 units per second. If it be assumed that the surface of evaporation be equal to that of the grate, and that either equals one square foot, the volume of steam which will be evolved per second will be 0.8 cubic foot, whence 1-1975th of a pound of water must be converted to steam each second for each square foot of grate, or of surface of evaporation, or, in terms of the volume of water, 0.9 cubic inch of water will be evaporated to steam, and 8-27 of a cubic foot (532 cubic inches) of water will be circulated and part with its heat each second. Thus it is evident that while the motive power to promote circulation is very great, the usual conditions of a boiler, with a restricted area of surface for evaporation, demand intense activity of circulation. (An example of higher temperature than  $212^{\circ}$  will be considered further on.)

While this current of steam and water is ascending a corresponding quantity of water which has lost its heat must descend, and unless provision is made to separate these currents, the conflict will add to the disturbances occasioned by the formation of bubbles. In a vessel or a boiler of considerable dimensions of width as compared with its depth, the conflict will take care of itself, and the velocity of circulation, induced from the expansion of volumes of the heated and partially evaporated mass, will establish a *regime* or equilibrium of action in the transfer of heat from the fire surface on the one hand and to the formation of steam on the other; and the steam bubbles will appear at that point in the column of water where the equilibrium may require them as agents for acceleration. If the water surface at the top of the vessel be not large enough (a not very unfrequent occurrence) for the steam to evolve itself in the course of a quiet circulation and surface evaporation, or for the bubble below the surface to develop in size without interfering with the return circulation from the top, it will then be found that a secondary circulation, under pressure from a column of foam, will have been established (Fig. 2), and the supply of return water for the bottom will be derived from below the evaporating surface. The heated return

water thus supplied will be again heated at the fire surface to a point higher than before, and the point of elevation where bubbles begin to form will be depressed, to correspond to the elevation of temperature. The bubbles will then develop and approach the surface laden with steam of higher temperature than would be sufficient to preserve a more quiet circulation, and will escape from the surface with some violence; of course a condensation into the disturbed particles of water will ensue, and the result will be the establishment of a strata of foam on the top of the legitimate circulation, and the passing off with the steam of a large quantity of water in the form of mist. This action can go on increasing in violence (with the intensity or extent of surface of the fire as compared to the volume or depth of water to which the fire is applied, taking into account the means of circulation provided) until the return water comes back to the point of application of heat—the fire surface—at such a temperature, that the amount of heat, there supplied, will generate a bubble of steam at once; when, at this moment, the circulation is interrupted by the tendency of such a bubble to rise within the return current; the next effort of the steam is to eject the mass of water within the vessel convulsively.

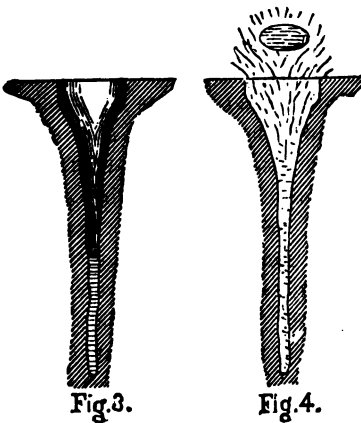


Fig.3.

Fig.4.

This phenomenon is that of the Geyser (Figs. 3 and 4). In this natural exhibition of a defective water circulation in a heated vessel, the sides of the Geyser tube or vessel are heated as well as the bottom—a condition incident to various steam boilers—and the vessel has a funnel shape, which is not so usual in boiler construction. In the normal state of a Geyser, or a mass of water in the small end of a natural funnel, is in active ebullition from

volcanic heat at the bottom (the constant supply of water being maintained by the dripping of springs in the upper part of the cone quite near the earth's surface); and at or near the time of an eruption the boiling water is in, or close upon, an equilibrium of circu-



lation or ebullition. By throwing sods, or substances of about the same specific gravity with the water, down the hole, the circulation is impeded, and a quantity of steam of greater pressure than what is due to the column of water is formed, until the mass of water is lifted from the bottom, and the bubble of steam thus evolved at the bottom will augment from the water surrounding it, especially as the piston of water above it gains in diameter and diminishes in thickness (as the funnel increases in size), *thus reducing the pressure upon the inclosed steam*. The heat of the bottom and walls of the tube will expand the volume of inclosed steam, and evaporate with great celerity the spray or such small quantities of water as may trickle down, and the two causes will preserve the pressure of the steam, beneath the water, to the point necessary for the production of the phenomena, notwithstanding the increase of volume. An eruption of much violence will follow—the whole column of water being expelled with great force, accompanied by the evolvment of steam from the mass of water in the air above.

After the ejection the fountain of water will have given out a large part of its heat; and if the time of exposure to the air were long enough, the temperature of the ball and spray would fall below  $212^{\circ}$ , while the Geyser tube would have been entirely relieved from pressure by the expansion and escape of the inclosed steam, so that the mass could fall back into the heated chasm. But not only will scarcely time enough have passed for the water to have divested itself of heat but the mass which falls will be a broken shower of intermingled steam, air, and water; and also the internal surfaces of the tube will have attained, from the absence of water in contact with them, a very high heat, which will be given out to the first small quantities of water which return, generating a large volume of steam, without loss of heat in heating water; and several successive discharges will occur before such degree of quietness is reached, as will allow the water to remain within the funnel; and even after this much turbulence will be exhibited before the regime of circulation will produce a stable condition of movement.

In my examples, Figs. 1 and 2, the phenomena of ebullition have been shown at the atmospheric pressure; and, although it is not intended at this time to carry this discussion beyond the mere ele-

mentary exhibitions, yet it may be well to make a similar sketch and computation at higher temperature.

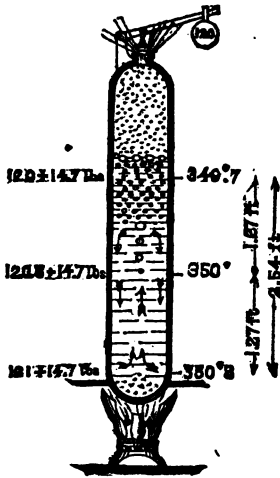


Fig. 5

Fig. 5 represents a vessel containing water exposed to the action of heat similar to those shown in Figs. 1 and 2 (ante), except that a permanent pressure of 120 pounds per square inch above the atmosphere is maintained, under which the generation of steam is supposed to be going on. In consequence of the expansion of water at higher temperature, the height of column which represents one pound pressure now becomes 2.54 feet (in place of 2.4 feet), and, in consequence of the properties of steam, the difference of temperature corresponding to one-half pound pressure per square inch becomes  $0^{\circ}.3$  (in place of  $1^{\circ}.65$ ). The other figures change as

follows: The latent heat at  $349^{\circ}.7$  becomes  $= 870^{\circ}$  (in place of at  $212^{\circ} = 966^{\circ}$ ). A pound of water has a volume of 30.9 cubic inches (in place of 28.8); a pound of steam has a volume of 3.3 cubic feet (in place of 26.36). The volume of steam as compared to the water from which it is formed at  $349^{\circ}.7$  is as 185 to 1 (in place of at  $212^{\circ}$  as 1,580 to 1). The mixed volume of steam and water at the surface will be but 1.06 times that of the solid water at 1.27 feet below, while the total column of mixed steam and water above the solid water is 1.03 times that of the solid water in this case (in place of 2.35 times at atmospheric pressure). It will be seen from this that the tendency to foam falls off rapidly as the pressure at which evaporation is permitted; increases when the bubbles cease to be so large an obstacle to the return circulation; and, also, that the motive power for circulation gained by the levity of the steam bubbles falls off with increase of pressure. The manifest effect of this deficiency in inducing circulation will be to move the point at which the bubbles will begin to form nearer to the fire surface (lower down in the vessel), and to *define the dimensions* of the streams of rising and returning currents. If the rising current is

small enough the bubble of steam may begin to form on the very bottom of the vessel, rise up enlarging in magnitude to the surface, enveloped all the while in a column of water of (in this supposed case)  $350^{\circ}.3$  temperature at the bottom—enlarging by relief of pressure, which acts in two ways; first, by permitting expansion, and, second, by causing evaporation into its (the bubble's) atmosphere, and, finally, the bubble of steam is evolved at the top quietly at  $349^{\circ}.7$ .



Fig. 6.

There are two other phenomena of boiling which should be stated here. The first of these is, to a great degree, experimental. If water is carefully heated in a nicely-formed vessel, Fig. 6, [first taking the precaution to boil it, so as to expel the air which all water absorbs into its volume in quantities relative to the temperature (diminishing with their increase)], applying the heat so as to preclude any disturbance in the course of circulation, the temperature can be elevated much beyond the boiling point without the commencement of ebullition.

Mr. Knight, the Secretary of the Franklin Institute, has succeeded in reaching a temperature of  $247^{\circ}$  in an open vessel, which indicates an internal tension for the water of about 14 pounds per square inch. Of course, the commencement of evaporation under these circumstances is a convulsive ebullition. The presence of a little broken glass, or of particles of any material of splintery form, will prevent the phenomena; and the introduction of any sharp object will almost certainly incite ebullition whenever the boiling point is exceeded.

This peculiar property of heated water seems to be the equilibrium of cohesion (before referred to), which is here manifested to the extreme of instability. The conditions by which it can be displayed are so limited that they can not be regarded as having a possible existence in any steam boiler, in which there is not the least probability of elevation of the temperature of the water above the boiling point (at any given pressure) by securing that quiescence which all experiments have shown to be demanded for the production of this result.

The second phenomena bears a more important relation to the steam boiler. It has already been shown that water will leave a

heated surface so soon as the temperature of the entire mass has reached that degree where the increment of heat imparted at the surface, upon which it should be brought in contact, will elevate the temperature above the boiling point properly due to the pressure from the mass; and it remains to be stated how a similar repulsion can exist without the temperature of the repelled mass of water being elevated in like degree. If we suppose a heated surface so hot and so well supplied with heat that its *radiant heat* will generate steam from the under surface of a mass of water of greater tension than the subsisting pressure of the atmosphere or inclosure, together with the pressure proceeding from the weight of the mass, the mass itself will be repelled from the heated surface and will float upon the vapor emitted. The familiar example is a drop of water upon a flat-iron; the philosophical one is that represented by



Fig.7.

Fig. 7, and is known as an exhibition of the *spheroidal* condition of water. Water supported in this way must be evidently in very unstable equilibrium, and, with the slightest inclination of the heated surface, would roll on its vapor to the lowest point, and a capsule or saucer-shaped vessel is therefore

indispensable to retain it.

In the course of the experiment very little heat is imparted to the ball of water, the radiant heat being spent mainly upon the under surface, while that which passes through this surface shines through the water as light shines through glass; thus, only the film, so to speak, of the under surface is heated, and much, if not most, of this heat upon the surface is at once expended in generation of steam. The little heat that is imparted to the water at the under surface, in place of establishing a circulation of water within the ball, simply disturbs the center of gravity, and induces the whole mass to roll over and allow its heavier (colder) side to find its equilibrium at the bottom; and in the operation, under the conditions stated, a spheroidal shape is assumed by the body of water.

Investigations have shown that when the surface of the vessel is heated to about 380° Fah. a spheroid of water of about two inches of thickness will be repelled and constantly supported, while the temperature of the water (with the air in a summer-hygrometric con-

dition?) will be about  $206^{\circ}$ , or  $6^{\circ}$  below the boiling point (Bou-tigny).

This recital of what constitutes the spheroidal condition (so-called) of water has been made, with so much explicitness, in order to render it apparent that it is merely a simple consequence to the laws of transmission of heat from a surface to water, and not an occult property in any sense. The statement of importance in boiler construction is, that at some temperature a heated surface will repel water, and that once repelled the surface will cease to impart as much heat as before, and the repelled mass of water can become of much lower temperature than it must have had if the contact had been preserved, and these truths apply to water under pressure (atmospheric or other), and to any height of column of water upon or above the heated surface, a relative temperature being accepted for the various conditions.

Whenever the water has been once repelled from a fire surface or plate, the temperature of that surface will increase with great rapidity, and the limit of this temperature of a plate it is difficult to fix. It is certain that where there are gaseous bodies on either side of a plate, the temperature of which bodies are known, the temperature of the plate itself will be a function of the capacity for heat of the two gaseous bodies in opposite contact; but even this complex law for obtaining the heat of a plate from which water has been repelled fails in the case of the fire box of a boiler, where half the heat from the flame is radiant heat which is absorbed into the plates of the fire box at an unknown temperature of intensity, although the quantity of heat may be well established. But I think it safe to assert that in less than one minute's time the temperature of a  $\frac{1}{8}$  inch plate in a fire box from which water has been repelled, will become over  $1,000^{\circ}$  Fah., and the plate will be materially reduced in strength to withstand the internal pressure.

I have not attempted to complete this application of principles to the locomotive boiler; in fact, I feel the deficiency of my elementary remarks in their want of comprehensive statement of circulation, where the return takes place from the back instead of downwards, as I have discussed; but I present these considerations as showing the direction of inquiry to be followed in the attempt to account for failures of fire-box sheets or of tubes whenever the evidence of over-

heating presents itself. In such cases, I have little question that obstructed circulation and inadequate waterspace have more to do with accidents than the quality or nature of the material of the plates. . . .

Mr. Briggs quoted an instance of the failure of some tubes in a class of locomotives constructed ten or twelve years since for the Illinois Central Railroad. In this case, a cluster of seven two-inch tubes, which were located about one foot down, upon the tube sheet, in its middle, in several engines of the same class, collapsed about one to two feet in front of the sheet. A sample of one of the collapsed tubes, which was furnished the speaker by Mr. Hayes of the Illinois Central Railroad at the time, showed a cup-shaped introversion without rupture of about six inches in length, the upper side of the tube having been depressed into the lower one completely. Of course the tube had been above red heat when this occurred. The remedy was understood to have been the removal of one or two vertical rows of tubes to allow the water to circulate.

Mr. WILDER, Erie Railroad—I move that a vote of thanks be tendered to Mr. Briggs for the instructive remarks he has delivered before us this morning.

Passed unanimously.

THE PRESIDENT—The continuation of the discussion on Locomotive Boilers will now be in order.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—As stated in this report, your Committee tried one or two experiments in regard to circulation, and if the Convention have no objection I will make a sketch to illustrate our observations. The Committee made a sheet iron box, running down eighteen inches, with a two and a quarter inch space between the ends made of plate glass; the joints were made with gum between the glass and the iron; charcoal was used as fuel. The top of the box went within an inch of the waterspace with a chimney extending out. Charcoal was put in and fire started, and we found as soon as the water began to warm perceptibly there were very minute globules of steam formed opposite the fire, which traveled upward slowly along the sheet, perhaps extending one-eighth of an inch from the sheet until they disappeared near the top. As the temperature increased the globules enlarged and extended farther out from the sheet, but we found on testing the water only a temperature of sixty degrees by placing the bulb in the water opposite the top of the grate; upon raising it to the top of the water the thermometer raised to one hundred and eighty degrees, showing that these little globules carried the tempera-

ture to the top of the water. After it commenced to boil the temperature increased at once to about the same at the bottom as it was at the top; but if the bulb of the thermometer was placed down close to the bottom we found a reduction of temperature below the boiling point one or two degrees. As the temperature commenced increasing and the water boiled more rapidly these globules extended further out into the waterspace, making curves in that direction for two or three inches, and the top of the water seemed to be almost filled up with steam in the shape of foam, probably for two inches down, and within that distance these steam globules, as they came out, filled the entire waterspace. It was noticed that the water would rise higher on the side next the sheet and turning over would run down on this side; placing pieces of wood, that would float, they would be noticed to leave the top and then come down to that point and be carried upward by currents of steam and water. The globules seemed to travel faster than the water did. That could be easily determined by noticing the particles of water; the wood would float but the globules would move faster than the wood. The greater the fire in there the more intense the heat and the larger the steam globules seemed to be about this point; a number would run together, the larger ones would come over and strike the sheet on this side and skip over and go back in the water again, but the large steam globules seemed to be formed on the top of the fire; large numbers were formed below, but were smaller than those above. We found also that in the corners of the fire box, looking down on it, there was a current running down the corners and up in the middle. When not boiling too violently there was a current down the outside sheet. That was the result of our observations in noticing the water as it boiled. (Applause.)

Mr. BRIGGS, Editor of the Franklin Institute Journal—Mr. President, by permission I would say that that agrees with my explanation with the exception that the fire was on the other side. The heat was felt all the way up, the elementary effect of the fire applied to the bottom of the boiler. The formation of steam took place at the same point where the pressure was relative to the elevation; the relief of pressure was equivalent to the temperature for two hundred and thirteen degrees, when it reached two hundred and thirteen it would come into violent ebullition.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—The conditions in the two cases are different; in one case the heat was applied at the side of the sheet and in the other at the bottom.

THE PRESIDENT—The hour appointed for the discussion of the report on Locomotive Construction has arrived, and that subject is now the regular order of business.

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—As the chairman of that Committee I may state that the material we had for making that report was extremely meager. I suppose that circulars were sent to all the members of the Association, and I think we got but twelve replies, and

many of them gave us but very little information on which to make a report. I simply make this statement on account of its brevity.

Mr. SETCHEL, Little Miami Railroad—It will be remembered that this subject was continued over from last year. The report then was mainly upon a new device for an engine commonly known as the "Roberts Engine," and you will remember there was a great deal of talk about it, and it was promised by Mr. Brooks and others of the Committee that we should have a complete report of the Roberts Engine at this time, showing what it had done, and how far it was an improvement over ordinary engines; as there is nothing said about it in the report I would like to ask the Committee whether it is a success or a failure, or what is the matter with it?

Mr. SEDGLEY, Lake Shore and Michigan Southern Railroad—Perhaps it would be in order for me to say a word in regard to that matter. At the time the Committee were together that subject was canvassed to some extent. The engine referred to is the first engine that has been produced on that principle, therefore there should be many changes made in its general construction which experience has pointed out. It has a boiler suitable for a fifteen by twenty-two inch cylinder; it is very small; the engine has a cylinder sixteen by twenty inches and a four foot six inch wheel. The engine has been at work on the Lake Shore Road for the last year, mainly running passenger trains, a portion of the time upon a train that has been perhaps making forty miles an hour while running, which we should consider an excessive speed for that sized wheel. We have no trouble in making forty or fifty miles an hour with five cars. The engine runs with perfect ease, but if you put eight or ten cars to the engine and undertake to make that speed the boiler is not sufficient, it will not furnish steam enough; but so far as the cylinders are concerned, and that is the only change from an ordinary engine, I have no doubt that an engine with a sufficient amount of heating surface and a wheel adapted to the service for which the engine should be used, will produce better results than the ordinary cylinder; but this is the first attempt to work at that problem, therefore there are many things that are wrong in the construction of the engine for the service in which we have used it. I have a statement made up, but it was left in my office; I could have given you the performance of the engine, the cost per car, the cost for fuel and repairs, but I have unfortunately left the document at home and can not speak from recollection.

THE PRESIDENT—Will you furnish that document so that it can be embodied in that report?

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—I can do so.



**Description of Engine Col. Roberts.**

Weight of Engine in Working Order.....65,000 pounds.  
 " " on Drivers.....41,000 "  
 Diameter of Drivers.....54 inches.  
 Cylinders .....16x20 inches.  
 Grate Surface .....13 feet.  
 Total Heating Surface.....798½ feet.  
 Travel of Valve.....5½ inches.  
 Outside Lap of Valve.....¾ inch.  
 Inside " " .....¾ inch.  
 Steam Port Openings.....1½x10½ inches.  
 Exhaust Port.....2½x10½ inches.  
 Exhaust Opening in Center Cylinder.....43½ inches.

The engine will steam well in freight or ordinary service with 4½ inch double exhaust tips.

*Statement showing Cost of Fuel Consumed by Engine Col. Roberts, (with the Roberts Central Exhaust Cylinders), during the year ending December 31, 1875.*

MONTH.	No. Miles Run by Engine	Cost per Mile Run for Fuel.	Cost pr Car pr Mile Hauled for Fuel.	No. of Cars Hauled One Mile.
January, 1875.....	500	.1070	.0178	3,000
February, 1875.....	2,131	.0652	.0112	12,400
March, 1875.....	780	.0730	.0146	3,900
April, 1875.....	348	.0919	.0200	1,600
May, 1875 .....	2,766	.0683	.0090	20,800
June, 1875.....	2,600	.0638	.0090	18,400
July, 1875.....	2,733	.0916	.0119	21,000
August, 1875.....	1,530	.0990	.0159	9,500
September, 1875.....	2,230	.0791	.0112	15,700
October, 1875 .....	1,630	.0628	.0100	10,200
November, 1875 .....	2,600	.0705	.0114	16,000
December, 1875.....	2,700	.0666	0.121	14,900
Total.....	22,548	.0745	.0114	147,400

Mr. HUDSON, Rogers Locomotive Works—As a member of that Committee on Locomotive Construction, I may say that I did not contribute any thing

toward the report. I was not able to meet with the Committee, and did not see the report at all until it was read here. There is one thing in it, however, that struck me as occupying too much prominence: I understood the report to recommend the consolidation engine in preference to locomotives of fewer driving wheels; and if the Committee do recommend that, I, as one of that Committee, should dissent. I think that is a question which ought to be left to the officers of the various roads to determine as to the character of the locomotives suitable to their business.

Mr. ROBINSON, of Canada—I would qualify this question further; I would ask whether the Committee recommend that engine indiscriminately for all kinds of freight service, or only for one special service?

Mr. FRY, Philadelphia & Erie Railway—I think I understand the feelings of the Committee with regard to the consolidation engine. In last year's report the use of the consolidation engine was recommended for exceptionally heavy freight service, such as pushing over heavy mountain grades or hauling trains over heavy curves. In this year's report they draw attention to the fact that one of the large railroads of the country has adopted the engine for hauling all its freight service, not only on heavy grades, but on the level divisions. It has been remarked often that but little progress has been made in locomotive engineering; that we are doing nothing to promote economy in transportation, so far as it is affected by improvements in the locomotive department. An attempt is being made to produce economy directly by alterations in the locomotive power; that is, by increasing the power used. The Committee, as I understand it, do not recommend the use of the consolidation engine, but merely give a number of facts which affect the cost of transportation. They desire to call the attention of the meeting to the use of these engines. It is important that we should collect information as to running engines on ordinary grades, and compare the cost of doing this work with what we may expect from the use of heavy engines. During the short time I have been connected with railroad work I have noticed a marked change in the opinion of railroad men as to what kind of train can be handled in the freight service. We used to consider that seventeen or eighteen cars was a heavy train on level divisions, and twenty-five cars was a very heavy train. I often heard the remark made that twenty-five cars were all that could be handled. When I went on the Erie Railroad we handled forty cars in a train, and they said there was no use in using a Mogul engine, as every-body knew we could not handle more than forty cars in a train. On the Pennsylvania Road this engine was adopted on what was practically a level division. It was placed on the track as an experiment. Strict instruction was given not to haul over sixty cars, but sixty cars were hauled so successfully that five special cars being ready to go out they put on sixty-five, and then seventy, and, finally, seventy-five and eighty, and now it takes no less than ninety cars with fourteen tons on each car. Now, if the transportation department can handle eighty cars

in a train the locomotive department ought to furnish them an engine that will haul them. As to the amount of destruction to the track by these heavy engines we have but very little information, nor as to what the cost of repairs would be, the consumption of fuel, etc. The Committee thought the attention of the Association could be called to the fact that this engine is being tried on a large railroad; and we ought all to be prepared to ascertain what the cost of transportation is on all the roads with which we are connected. It is by no means a final recommendation of this consolidation engine.

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—I would state to the Convention that the Committee did not recommend, as a committee, the consolidation engine, neither did we feel at liberty to withhold the information that we had in regard to that class of engines. I would inquire of Mr. Hudson the nature of his objections to that part of the document. I do not know whether you might consider it a part of our report. I, for one, did not feel at liberty to withhold that from the Convention; and I hope we shall have the freest discussion in regard to it. As regards the Roberts engine, it was understood that Mr. Brooks, of the Brooks Locomotive Works, would have considerable to say in the Convention in regard to that engine. I hope he will be here before the close of the Convention.

Mr. HUDSON, Rogers Locomotive Works—I may say that I did not intend to criticise or find fault with the consolidation engine, but I think if the Committee were understood to recommend that engine I should dissent from that recommendation. I think the type of engine suitable for any road ought to be determined, and possibly will be. I know that such things do occur—that the officers of a road determine the character of the motive power on their road; and I will say that if I were constructing a locomotive for a certain duty, if one pair of driving wheels would do the work I would not put two pairs under it, nor more than two pairs if two pairs would do the work. But, if compelled to put more than two pairs to distribute the weight, I would use three pairs, but no more than that if that would be sufficient to do the work. But I think there is a limit somewhere, and it must be determined by the requirements of the service.

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—If it is in order, I will call for the reading of that part of the report which relates to the consolidation engine. I think there are many members here who did not hear it read.

THE PRESIDENT—I would state to the Convention that Mr. Dripps, formerly of the Pennsylvania Road, gave me some figures last evening of some experiments made by him with eight-wheel, ten-wheel, and consolidated engines. Mr. Wells has it in his hand, but, perhaps, will not give the information as to the amount of resistance at ten miles an hour.

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—We would be very glad to have that information.

**THE PRESIDENT**—It is mostly in figures.

**Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad**—These diagrams represent an ordinary eight-wheel passenger engine, as used on the Pennsylvania Railroad. There are three classes of engines. In this one the diameter of the cylinder is 16 inches; stroke, 24 inches; driver, 60 inches; weight on drivers, 24,000 pounds each driver; total on drivers, 48,000 pounds; total weight on truck, 20,500 pounds; weight of tender, loaded, 32,600 pounds; friction on engine coming round a curve at ten miles an hour, 19,600 pounds. It does not state the degree of the curve nor the radius. The experiments were tried on the same curve. This diagram is a freight engine, No. 1,119; diameter of cylinder, 18 inches; length of stroke, 22 inches; diameter of drivers, 55 inches. This engine has three pairs of driving wheels and an ordinary truck. The weight on the three pairs of drivers is 52,800 pounds; on the truck, 22,600 pounds; weight of tender, 47,700 pounds; friction going round a curve ten miles an hour, 17,500 pounds, being less than the ordinary eight-wheel engine, in which it was 19,600 pounds. This one is the consolidated pattern; diameter of cylinder, 20 inches; length of stroke, 24 inches; diameter of drivers, 49 inches; total weight on four pairs of drivers, 78,500 pounds; weight on single pair of wheels, 19,700 pounds; friction going round a curve at the rate of ten miles an hour, 18,500 pounds. This is 110 pounds less than in the ordinary eight-wheel engine. The friction in the Mogul pattern was 17,600 pounds, and in the consolidation engine 18,500 pounds. It seems to me that this matter might be gotten up in some form by the Secretary and published in our report. It might be useful in the discussion of this subject; and whatever additional information the Secretary can get from Mr. Dripps might be arranged in some form and printed in this report.

**Mr. SPRAGUE, Pittsburgh**—I suggest to Mr. Wells that he couple it with a request to the Secretary that he should try to get the length of the wheel base of the different engines, and the degree of curve on which the different engines were tried.

**Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad**—I accept the gentleman's amendment.

The motion was then agreed to.

PHILADELPHIA, PA., Aug. 31, 1876.

**J. H. SETCHEL, Sec'y American Railway Master Mechanics' Association:**

DEAR SIR.—Agreeably to your request I herewith send you a history of the experiments made at Renova, Pa., on the Philadelphia & Erie Railroad with three different classes of locomotives—eight-wheel, ten-wheel, and consolidation class—to ascertain the

amount of frictional resistance of each class of locomotive in passing over a curved track.

The dynamometer used in making these experiments was an instrument designed and put in use by myself. The instrument is fastened permanently to the floor of the car, and is arranged with rollers, through which a roll of paper traverses.

A pencil bar is connected with the draw bar of the car, which records upon the moving paper the amount of force exerted. The paper receives its motion direct from the car axle. The instrument is self-registering, both when going ahead and when backing.

These experiments were made with locomotives belonging to the Philadelphia & Erie Railroad Co., upon the Shintown curve, near Renova. The curve is one of  $4^{\circ}$ ; radius, 1,432 feet.

The locomotives were in good working order, and were generally taken for the experiments as soon as detached from their trains; the only preparation necessary being to disconnect the piston rods from the cross heads, so as not to have the friction of the pistons in the cylinders; all other connections were left precisely as if running by steam, so that the friction due to all the working parts of the locomotives, except the friction of the pistons within the cylinders, would be indicated.

The locomotives experimented with were pulled by another locomotive. I am aware, however, that the proper plan would have been to have pushed the locomotive experimented with ahead of the dynamometer car and working locomotive; but, owing to the presence of considerable snow on the ground, the wind occasionally blew snow on the rails, which was more convenient to remove by placing a locomotive ahead to pull the locomotive experimented with. For this reason the locomotives were pulled during the trials instead of pushed.

During all these experiments the speed was kept as near ten miles per hour as possible.

I was personally assisted by W. A. Dripps and W. L. Foster, Master Mechanics of the Philadelphia & Erie Railroad, and I know that the experiments are correct and can be relied on.

Accompanying this I send you a tracing, showing a diagram of the three different classes of locomotives experimented with, giving the length of wheel base, total weights, the distances and weights

of the bearing points on the rails, and the friction in pounds, as taken from the dynamometer diagrams of each class of locomotives, which data gives a true comparison of the friction on curves as generated by the different classes of locomotives.

These experiments prove, conclusively, that heavy locomotives, properly designed, with a short wheel base, and with as many bearing points on rails, within such base, as practicable—thus reducing the weights on each bearing point—will pass around curves with less friction, and be less destructive to the track, than the ordinary passenger locomotives of much less weight. Of course, these heavy locomotives are best adapted for slow speeds, and will show the greatest economy, and will work to the best advantage, on railroads having a double track, heavy grades, and a heavy freight traffic.

The effective power of the "consolidation class" of locomotive is fifty per cent. more than the ordinary six-wheel connected freight locomotive; and, from actual service, I find that locomotives of this class work up to their power fully as well, in fact, better than the six-wheel connected locomotive. Two locomotives of the "consolidation class" will do the same work—haul as many cars—as three of the six-wheel connected locomotives; and, as three of the six-wheel connected locomotives, when new, will cost \$10,000 more than two of the "consolidation class," there is thus a saving of \$10,000 in the original outlay, and the saving of wages of the crew of one locomotive daily; and, with a properly constructed locomotive of the "consolidation class," the running repairs for tonnage hauled will be less than any other class of locomotives now in use.

I am, yours very truly,

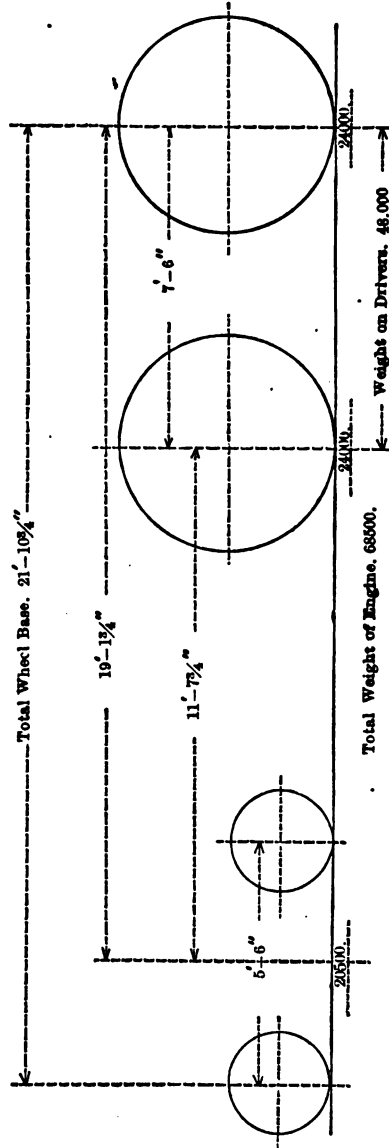
ISAAC DRIPPS.

MR. HUDSON, Rogers Locomotive Works—I would like to ask how the resistances were determined?

THE PRESIDENT—I had a conversation with Mr. Dripps; he said he used a dynamometer that was very sensitive and would work within a few pounds; he was a long time in getting these results; the experiments were commenced two years ago. During the life of J. Edgar Thomson he did not feel at liberty to make it known, but as the road had now adopted the engine there were no objections. He was making other experiments and would be glad to furnish the results to the Association.

MR. HUDSON, Rogers Locomotive Works—Was the dynamometer applied

# Passenger Engine No. 1034, Philadelphia & Erie Railroad.



Diameter of Cylinder, 16 inches.

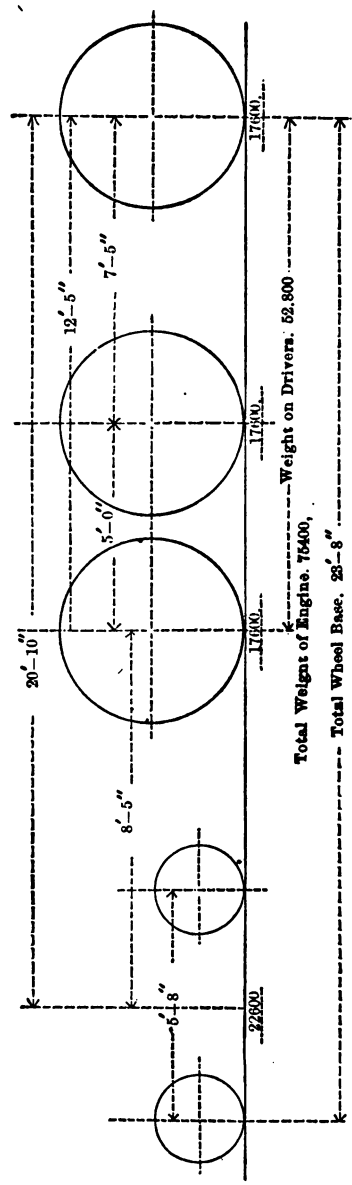
Stroke of Piston, 24 inches.

Diameter of Drivers, 60 inches.

Weight of Tender, loaded, 32,600 pounds.

Friction going around curve at ten miles per hour, 1,963 pounds.

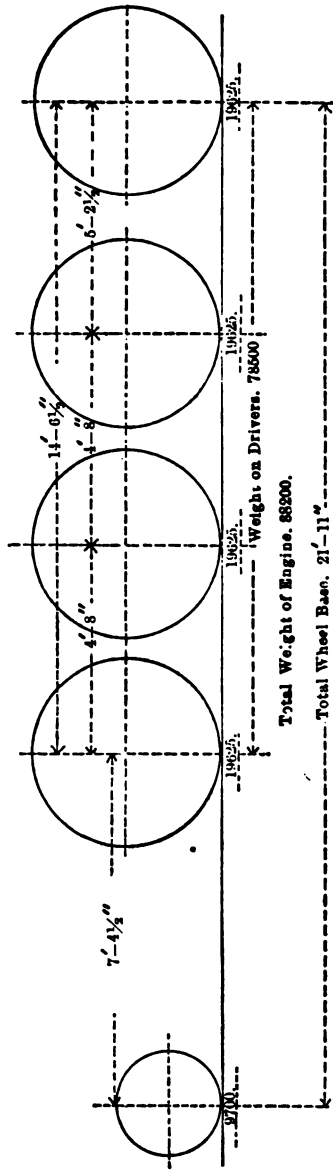
Freight Engine No. 1119, Philadelphia & Erie Railroad.



- Diameter of Cylinder, 18 inches.
- Stroke of Piston, 22 inches.
- Diameter of Drivers, 55 inches.
- Weight of Tender, loaded, 47,700 pounds.
- Friction going around curve at ten miles per hour, 1,760 pounds.



**Freight Engine No. 1716, Philadelphia & Erie Railroad.**



**Diameter of Cylinder, 20 inches.**

**Stroke of Piston, 24 inches.**

**Diameter of Drivers, 49 inches.**

**Weight of Tender, loaded, 47,700 pounds.**

**Friction going around curve at ten miles per hour, 1,850 pounds.**

o the locomotive and pulled by another locomotive, or how was it? for I think it has an important bearing.

THE PRESIDENT—That information I will have to request from Mr. Dripps, who is not present, unless, perhaps, Mr. Stratton can give us that information.

MR. STRATTON, Pennsylvania Railroad—The dynamometer car used is a car with a suitable apparatus in it, arranged with rollers carrying paper through; it was connected with the axle of one of a pair of wheels, so that the rate at which the paper traveled was in exact proportion to the speed at which the car was running. This dynamometer was connected with the bull-nose, and the spring used was tested by standard weights; the resistance put upon the spring was known in pounds. This dynamometer was self-recording, automatic in its work. The car was placed between the engine hauled and another one, so that the resistance was recorded on a dial which connected sensitively either when the car was being pulled or pushed against the engine. The spring was tested by test weights, so that there was no resistance from friction at the testing, and I believe that by some experiments made since that the records taken with that car are absolutely correct to within a very few pounds. The recording apparatus will work as well when it is used pushing a car or pushing a train or engine. If the car is used between an engine hauling a train on a grade or on a level when the brakes are applied it will record the resistance made by the application of the brakes, either one brake or more. It was noted that Mr. Dripps had been making some further experiments which he intended to give the Association the benefit of; I presume he is working them up now, but I believe they are not completed so that he can give them to the Association at this time.

MR. HUDSON, Rogers Locomotive Works—I think that hardly throws sufficient light on the subject. I apprehend that either pushing or pulling a locomotive, to determine the resistance upon a railway curve of a given radius, it is not shown what that resistance would be when the locomotive is working itself. I apprehend it is very different whether you pull the locomotive, whether you push it, or whether it furnishes its own locomotive power, and I will take exception to any pushing or pulling as indicative of resistance without the cars furnishes its own working power.

MR. WELLS, Jeffersonville, Madison & Indianapolis Railroad—It seems to me that this can only be of value as a comparison between different kinds of engines, all being used precisely alike under the same conditions or on the same curve; the only value is to determine the difference between different styles of engines. It probably will not register precisely the resistance of an engine furnishing its own power in going around a curve, but will show the difference between the different kinds of engines under the same circumstances.

MR. EDDY, Boston & Albany Railroad—Were these engines connecting rods and all the main connections on, or were the connecting rods withheld, thus running on the driving wheels without being in complete running order? I

do not know but an engine with three or four pairs of driving wheels will run easier up hill than an ordinary engine; but I do not believe it will.

Mr. GARRETT, Pennsylvania Railroad—The main rods were taken off all the engines used while making the experiments.

Mr. EDDY, Boston & Albany Railroad—I do not believe it is a very good experiment to put on record here; the engine was not in working condition. If these rods were on, and nicely adjusted, they would run very nearly as any other carriage would run upon the road, and the connecting rods would have very little effect to help them along or hold them back. It is the result of the experiments that I would not vote to go on our records. It would take some time to convince the mass that an engine with six or eight wheels connected will run easier than four wheels connected when they are in service.

Mr. ROBINSON, of Canada—I would like to ask at what speed these consolidation engines are supposed to run, and whether any difficulty is experienced with them in the general way of work.

Mr. FRY, Philadelphia & Erie Railroad—I would say there being but very few of these engines run they have to work among the regular trains on the schedule; they have to run the regular rates of speed of other trains. It is quite common to see them running express trains. No more trouble is found in hauling on a level than on a hill; they do not pull the drawbars out particularly there.

Mr. EDDY, Boston & Albany Railroad—I would ask if accepting that report from the Committee places it on file?

THE PRESIDENT—It becomes part of the proceedings of this Convention, and is embodied in our report, but that does not indorse it.

Mr. EDDY, Boston & Albany Railroad—If it is in order I move a reconsideration of the vote by which it was accepted.

Mr. HUDSON, Rogers Locomotive Works—I second it.

Mr. EDDY, Boston & Albany Railroad—I do not believe it is such information as we ought to impart to the world; I do not believe it is a correct thing to go by. It is merely taking a car or carriage and hauling it along on the road and seeing whether it will go easier or harder than another car. The reason I move that is because I have had considerable experience with engines similar to these, and invariably all are well satisfied that there is a great deal of friction there; it takes a great deal of their power to propel themselves, and they run much harder and with much more friction and more wear and tear of the track than a common eight-wheel engine.

Mr. JOHANN, Toledo, Wabash & Western Railroad—I can not agree with Mr. Eddy on the point that he takes for having that matter reconsidered; I look upon it as a matter for the information of the Association. We meet to interchange our views and ideas, and I see no reason why that subject should not be very beneficial and why it should not go on our records for information. As I understand the document, it is not an expression of opinion; it simply shows the degree of friction in these three classes of engines

coming around a certain curve. This point I would be glad to be informed upon, and therefore I shall vote no on Mr. Eddy's proposition, and shall vote decidedly yes for it to go in our minutes.

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—Before this vote is taken, if it is in order, I hope the document will be read for the information of the Convention. I do not understand that the Committee as a Committee has endorsed that as a part of the report; we have received it as facts. I do not wish to exclude from this Convention and the public any facts pertaining to locomotive service, and therefore should be glad to have the document read.

Mr. PHILBRICK, Maine Central Railroad—I do want to say this: Mr. Dripps, as I talked with him some time ago, brought up some things very new to me, some very different from what I supposed to be the case. He has managed this thing with great care; the experiments have taken a great deal of time, and he is a man with a standing that ought to have our respect, and whilst I have every respect for the man who makes the motion to reconsider—his standing we all know; he is a man I looked up to twenty-five years ago—I hope this meeting will not reconsider it. It is got up with great care. Though these things look to us very new, we can not say whether they are true or false; I would be glad to give Mr. Dripps an opportunity to explain them.

Mr. ROBINSON, of Canada—I would ask Mr. Eddy if he understands that when we receive a report we do not necessarily adopt it?

Mr. EDDY, Boston & Albany Railroad—I understand that we do adopt it, as it goes on our records and goes into our printed report.

Mr. SEDGLEY, Lake Shore & Michigan Southern Railroad—Will the Secretary please read that portion of the report relating to this matter.

The Secretary read the portion called for.

Mr. EDDY, Boston & Albany Railroad—I would like to know the sizes of the two engines—of what they call the six-wheel engine and what they call the consolidation engine. It takes sixteen of the six-wheel engines to do as much work as eleven of the consolidation engines. Will the Committee give us the proportions of the two engines, which I believe I did not hear.

Mr. FRY, Philadelphia & Erie Railroad—The ten-wheel engine was a standard engine formerly of the Pennsylvania Road, 18 inch cylinder, 22 inch stroke; size of the wheel, 55 inches; the consolidation engine is a 22 by 24 inch cylinder, with a 49 inch wheel.

THE PRESIDENT—I will say that on the drivers the weight is 24,000 pounds; on the Mogul is 17,600 pounds, and on the consolidation it is 19,625 pounds.

Mr. FORNEY, Railway Gazette—I have listened to this discussion with a great deal of interest, but it seems to me that the most important point has not been brought forward. Mr. Fry has said that the size of the trains amounts to ninety cars. Now is it more economical to haul trains of ninety cars with the consolidation, or seventy cars with the Mogul, or forty with the

ordinary four-wheel connected engine? In considering economy it is not alone necessary to look to the consumption of fuel, but there are many other expenses: the wages of the engineer and firemen; these distributed over ninety cars make a very much less sum to each car than as if distributed over forty cars. By the use of the consolidation one engineer and fireman will take ninety cars; the same is true of the wages of the freight conductor; the same is true of the brakemen; so that the total train expenses must be considerably less than when carrying trains of half that number or less. This is worth the attention of the Association.

Mr. ROBINSON, of Canada—I take the subject to be very much analogous to the broad gauge and the narrow gauge; we are at the opposite extreme of what we were two years ago. Take a four-track railroad, two tracks entirely devoted to freight service, on such a road the more cars you can pull the better. If we pull about a hundred cars and stop only for water, this would be the maximum of economy; but if running on two tracks the expenses of wear and tear would be too great. A six-wheel engine will be best for that kind of service. The style of engine that a road adopts is entirely according to the traffic of that road.

Mr. EDDY, Albany & Boston Railroad—Is the capacity for generating steam in these two different classes of engines as sixteen to eleven, or will an extra pair of driving wheels help a boiler to make more steam? (Laughter.)

Mr. HUDSON, Rogers Locomotive Works—I think there is another question connected with this, and I think it is covered by the statement which I made, that the officers of a road must determine the proportion and number of driving wheels that they will have; but the point is this, it will take more power to pull a hundred cars than it will to pull fifty, and the hundred cars or the forward end of the hundred must be strong enough to stand the pull put upon them; I have heard of such a thing as the ends pulled out of cars. It is a question as to how strong the cars can be made as well as how many cars can be pulled safely, without adding materially to the repairs of those cars. That is a question to come into the account, whether the repairs to the cars, pulling a hundred to the train, will not exceed the repairs to cars running in smaller trains.

Mr. ROBINSON, of Canada—A four-track road and stopping only for water would obviate this objection. It is not the pulling of the cars that hurts them, it is the jerking starting and stopping.

Mr. FRY, Philadelphia & Erie Railroad—I will reply to Mr. Eddy, first, that I did not think the authorities at Reading attempted to get steam by putting another wheel under their frames, but steam is provided in sufficient quantities. In reply to Mr. Hudson I would say we have found, as Mr. Robinson says, that the destruction of drawbars in cars is more due to jerking than any excessive pull. This was discovered in hauling over heavy grades; it was found that engines were hauling just as hard as they would do if hauling a heavy train on a level road, and the drawbars were not broken to any great extent. One incidental advantage on level divisions with heavy en-

gines that have ninety cars is the load behind the engines is not so severe, and they start these ninety cars with greater ease than with a smaller engine working up to its fullest capacity. A smaller engine would have to take a slack; no particular difficulties have been found even upon a one-horse road where we have been trying the engines; we have four trains to be hauled upon the road, and have fewer crossings and can make better time. The whole thing is in an experimental shape and it is in its infancy, and there are many elements to be determined before it can be said that it is profitable to use it.

**Mr. FORNEY, Railroad Gazette**—Mr. Eddy speaks about putting an additional wheel under the boilers; of course, no man present would say that the addition of a pair of wheels would make steam. Generally, the persons in charge of a road limit the weight of engines to the wheels. If the maximum weight on a pair of wheels is 24,000 pounds, and you want a boiler of larger size than was used on that engine, that boiler would weigh more, consequently it is necessary to put an additional pair of wheels under it to sustain the weight of the boiler; so, if you want additional boiler capacity you must have more wheels. I am not prepared to state that ninety-five cars in a train is more economical than half that number; but it is worth while for this Association to look into that question—to see whether cars can be carried more economically in large trains than in small ones. There are more railroads than there is business, and every railroad manager is studying economy in every way. Those who do business most economically are the ones who will survive. Roads are being undermined by low rates of freight they are compelled to carry.

**Mr. EDDY, Boston & Albany Railroad**—I said I had nothing more to say. The principal question that I wanted answered I have got no reply to. I did not suppose anybody would take up what I said about an additional pair of wheels; I asked the capacity of the boilers of those two engines, and it remains unanswered.

**THE PRESIDENT**—Mr. Fry, can not you give that answer?

**Mr. FRY, Philadelphia & Erie Railroad**—The sketch submitted shows the leading dimensions. The fact that the engines have been for months hauling the trains shows that they have the capacity.

**Mr. FORNEY, Railroad Gazette**—Those that have been built have about fourteen or fifteen square feet of heating surface; an ordinary boiler has from nine to ten.

**Mr. COOLIDGE, Fitchburg Railroad**—I have refrained from taking any part in this discussion, because I have had no practical experience with consolidation engines. It seems that the point at issue has not been touched upon. It may be demonstrated by any one with a very few figures. Let us see what are the two points to be gained. One is to make available the weight of the engine by what is called increased adhesion. This requires more connecting rods, more wheels. I have had some experience with what is called the great Mogul engine, and I will illustrate by a few figures.

I think the weight of a standard American engine is about thirty tons, distributed—eighteen tons on two pairs of driving wheels and ten or twelve tons on the trucks. While I am not posted about the consolidation engine, I may say, with the Mogul it is distributed somewhat differently. Their gross weight is thirty-five tons, five on the truck—one pair of trucks—another thirty on the driving wheels. It must be evident that in one case we have thirty tons available for friction; in the other, eighteen or twenty. There is a difference of five tons in the gross weight of the engines. I have had experience with only two of these engines. One has been in service between three and four years; it has a cylinder 17×24, five feet driving wheels, five pairs of drivers, and one pair of trucks, and weighs thirty-five tons. The average train of a 16×24 engine would be twenty-two to twenty-five cars—twenty-two cars loaded, with ten tons to the car, or twenty-five cars and freight cars are generally loaded. The Mogul engine takes from three to five and seven cars more than this number with the same amount of fuel as a 16×24 engine, which, I think, in point of fuel, is in favor of that. In regard to the friction in this class of engines, and the wear on the track, I have never been able to see that it is any greater. Are the points gained by making available all this weight offset with the disadvantage of having more coupling rods and more wheels? Any man can determine that in his own mind without any experience. I will give one other illustration. We have an engine which has not been so long a time in service as the other. I can not give the data as to fuel. It has five feet drivers, weighs thirty-six tons, thirty on the drivers and six on the trucks; and, whereas the ordinary standard will draw thirteen cars, this draws with ease eighteen and twenty cars. From this each can draw his own conclusions, and can form his estimate without any practical experience, by the figures.

Mr. CLARK, Lehigh Valley Railroad—I move that the discussion on this subject close.

The motion was carried.

THE PRESIDENT—Discussion on the report of the Committee "On the Best Material, Form, and Proportion of Locomotive Boilers and Fire Boxes" is now in order.

Mr. ROBINSON, of Canada—I move that the discussion on this report be now closed.

The motion was carried.

THE PRESIDENT—The next business in order is the report of "the Committee on Locomotive Tests," of which Mr. Forney is Chairman.

Mr. FORNEY, Railroad Gazette—We have received a great many statistics, which have been sent to the printer to be set up in tabular form, but for some reason the table has not been sent in, so I am not able to distribute it. It will come into the hands of the members with the Annual Report, and we hope you will study them, so as to understand the subject by next year.

### Report on Locomotive Tests.

*To the American Railway Master Mechanics' Association :*

GENTLEMEN.—Your Committee, appointed two years ago to make a report on locomotive tests, issued the following circular some months before the meeting of the last Annual Convention :

*To the Members of the American Railway Master Mechanics' Association :*

“Nearly all Master Mechanics, in order to determine the relative economy of different kinds of locomotives, or of methods of construction, are in the habit of making experiments, the results of which are recorded with more than ordinary care and accuracy. At the last Convention of the American Railway Master Mechanics' Association it was suggested that if these records could be obtained and embodied in the form of a report, that the data thus collected and published would have very great value. It was also thought probable that, if the attention of the members of that Association was called to the subject, some of them who have not heretofore made such experiments might be induced to do so. A committee was, therefore, appointed to request members ‘to make experimental tests to show the performance of locomotives, and to report the results to the Association.’ This Committee, therefore, desire to receive records of *any* experiments which members have made, or may make, with locomotives, to determine their performance. In order to indicate the kind of information and data desired, and also the methods of making experiments of this kind, the Committee will state that it is desirable to know :

“1. The kind of locomotive employed in the experiment, its total weight, the distribution thereof on the wheels, and the principal dimensions of the boiler and engines, their condition, and the length of time it has been in service.

“2. The weight of the train, the distance run, the running time, the grades and curves of the road.

“3. The kind of fuel used, and the weight consumed in hauling the train.

“4. The quantity of water evaporated in doing the work.

“5. The steam pressure employed.

“6. The temperature of the gases in the smoke box.

“7. The temperature of the fire in the fire box.



"8. The action of the steam in the cylinders, as shown by indicator diagrams, taken at different speeds and points of cut-off.

"9. The date of the experiment, and the temperature of the air, as indicated by an ordinary thermometer.

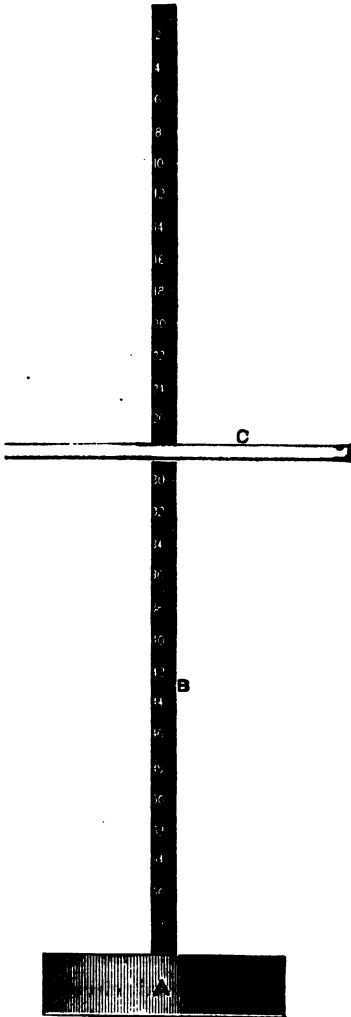
"The kind of engine employed can be shown best by a skeleton drawing, which will represent the principal parts only, with dimensions marked on it; but a photograph of the engine is better than nothing. The engine should be weighed in exactly the condition it is in when working, and with two men on it, but uncoupled from the tender. It is important, however, to *know* that the scales used weigh correctly, which, it is hardly necessary to say, ordinary track scales often do not. It is also desirable to know the quantity of water which the boiler carries. To determine this first weigh the engine with the water at the height at which it is ordinarily carried on the road; then blow *all* the water out of the boiler and weigh the engine again. A suitable blank form is appended hereto, in which the weight and dimensions of the engine can be conveniently entered.

"The weight of the train would, of course, be most accurately obtained by weighing each car. When this is not practicable state the number of cars, the number of wheels under each car, and whether they were loaded or empty. The distance run is, of course, easily obtained. The running time should be recorded either with a speed indicator, or by some one noting the time of passing each mile post, and of arriving at and leaving stations. The grades should be shown by a profile of the road, on which the radius and length of each curve should be marked.

"It is best, if bituminous coal is used in experiments in which great accuracy is aimed at, to pick the fuel and use lumps of coal only, because otherwise it is impossible to tell what proportion of that used is fine coal or dirt. Before making the experiment the tender should be carefully swept out, and all the fuel, including that used for kindling, should be *weighed* on scales that are *known* to be accurate. The remaining coal, when the run is completed, should again be weighed, and, of course, be deducted from that first taken. The kind of coal used should also be noted.

"The quantity of water evaporated should be determined by a gauge, consisting of a wooden float, similar to that represented in

engraving. It consists of a wooden float, *A*, which is placed on surface of the water, through the manhole of the tender. A



wooden stem or rod, *B*, which is graduated in inches, is attached to the float. This rod moves easily through a hole in a board, *C*, which is placed in the coping of the manhole. By observing the height at which this gauge stands after and before the tender is filled, the difference will, of course, indicate the number of inches of water used. Before making the experiment the quantity of water contained in each inch should be ascertained by placing the tender on the scales, and then measuring the height of the water and weighing the tender. The water may then be allowed to run out until the gauge indicates 12, or any other number of inches less than at first. If the tender is then weighed again, the difference between the first and the last weight will give the weight of the number of inches of water indicated by the gauge, from which the weight of an inch in height of water in the tender can easily be obtained. If the quantity of water in the boiler before and after the experiment is the same, that which is drawn from the tender will, of course, represent that which has evaporated, provided none has been wasted by leakage, priming, or by the

ctor, or for wetting coal, or other purposes. Care should therefore be exercised that there is no waste of water for these or other causes.

"The pressure of steam should be recorded, either by a recording gauge, or by placing an intelligent boy on the engine and have him note the pressure once every minute while the engine is running.

"The temperature of the gases in the smoke box may be obtained by using two pyrometers. Two should be used, so that the one may be a check on the other. A record of these should be taken once every minute while running a distance of ten or twelve miles on a level piece of track, and again while going up the steepest grade on the part of the road on which the experiments are made.

"The temperature in the fire box can be obtained if a piece of wrought iron of known weight, say 60 pounds, is placed in the fire until it is heated up to the temperature of the fire, and then removing it quickly and placing it in a vessel (of wood preferably) containing a known weight of water, say from 60 to 100 pounds, and observing the temperature of the water before the iron is put in, and after, say in ten or twenty minutes, when it has communicated all its heat to the water. These phenomena must, however, be observed and recorded with great care and accuracy, as a trifling error will lead to very erroneous results.

"The indicator diagram should be taken in the ordinary way, with the throttle wide open, and the speed with which they are taken noted. The speed can be known if an attendant will count the revolutions of the driving wheels for any given time when the diagram is taken. At ordinary speeds this is possible, but when running fast a revolution counter or speed indicator will be necessary to be sure of a correct count.

"The Committee, of course, do not expect to procure all the data enumerated above from any ordinary experiments, and, therefore, they request members of the Association to send records of *any* experiments which they may have made recently, *even though the data recorded may be of only one or more* of the phenomena described above. Carefully made experiments, with an accurate record of all the facts referred to in this circular, would, however, have exceptional value at the present time. If experiments are made with engines of peculiar construction, or under unusual circumstances, members are requested to furnish drawings of the peculiarities, and describe the circumstances attending the experiment."

[Here followed a suitable blank for the dimensions and weight of the locomotive experimented with.]

As the Committee did not receive any replies to the first circular, a few weeks before the meeting of the last Convention they issued another, as follows :

*"To the Members of the American Railway Master Mechanics' Association :*

"As the Committee on Locomotive Tests, appointed by your Association, have thus far not received any reports of such tests, they desire to call attention to the last paragraph in the circular referring to this subject, which the Committee issued, and which reads as follows :

"The Committee, of course, do not expect to procure all the data enumerated from any ordinary experiments, and, therefore, they request members of the Association to send records of *any* experiments which they may have made recently, *even though the data recorded may be of only one or more* of the phenomena described.

"As the object of appointing the Committee was simply to collect together the records of experiments or tests which the members have from time to time made, the Committee request them to forward reports of *any* such experiments made within the past few years, even though ~~no~~ other record of the performance of the engines was kept than the amount of coal consumed and the number of cars hauled. There are a great many reports of this kind in existence, which, if collected together and made accessible, would be very valuable. The Committee, therefore, desire to urge members having such records to forward copies to their Chairman as early as possible."

To the latter no replies were received containing sufficient information to enable the Committee to make a report, with the exception of a very valuable paper from Mr. Reuben Wells, of the Jeffersonville, Madison & Indianapolis Railroad, which was handed in too late to report.

This year the Committee issued a circular as follows :

"The Committee on Locomotive Tests, who were appointed at the Seventh Annual Convention of your Association, and who were instructed 'to request members to make experimental tests to show the performance of locomotives, and to report the results to the Association,' were obliged to report at the last Convention that they had not received a sufficient number of replies to their circular to make a report. As the Committee was continued for another year,

they renew the request made to members of the Association, in previous circulars, to send reports of experimental tests made to determine the performance of locomotives. In the first circular the Committee issued they gave somewhat full particulars of the kind of information which they desired. They will add that they want reports of *any* locomotive tests in which the performance, such as the amount of fuel consumed, water evaporated, load hauled, distance run, and speed of train is accurately recorded. Members who either have made, or will make, such tests, are requested to forward records thereof to M. N. Forney, Chairman of the Committee, No. 73 Broadway, New York."

To this a number of reports of experiments made on different roads have been received, some of them containing information of much value, but at the same time the Committee are compelled to state that up to the present time no series of experimental tests on the performance of locomotives, which were at all comprehensive, have been made, or to their knowledge undertaken. That such tests would have very great value and would indicate how a very large saving may be effected, the Committee hope to be able to show from the reports which they have already received. These have been tabulated, so that their results may more easily be compared with each other. Before referring to them, it may be well to state that the object of such tests, as understood by the Committee, is to indicate how goods and passengers can be carried on railroads with the least cost. This is, however, a very complicated problem, and in the solution of which, if proper regard is not given to all the conditions and circumstances which influence it, serious error and entirely false conclusions may result. Thus, if in estimating the performance of a locomotive, regard is given solely to the amount of fuel consumed, we may find that with a very small consumption of fuel per car per mile, there may be other expenses incurred which will increase the total cost of moving the trains and offset any possible saving in fuel. It may, for example, be stated generally that the cost for wages of locomotive runners and firemen is equal to the cost of fuel. If, then, by reducing the speed of trains one-half, twenty per cent. of the fuel is saved, it is obvious there would be no saving in train expenses, but a loss, because the wages of locomotive runners, firemen, and other train hands would be doubled. Or if by hauling thirty cars in a train the cost of fuel per car per mile is ten per cent. less than it

would be if forty are hauled, then it is also obvious that the total cost is increased, because in the one case the work performed by the runner, fireman, and conductor is one-third greater, whereas the cost of fuel is only reduced ten per cent. It will be seen, then, that in order to make any comparison of the economy of locomotive performance *all* the train expenses should be taken into account. The Committee has therefore prepared a table with headings for the principal dimensions of the engines, character, size, and speed of train hauled, number of stops, character of road, kind, quantity and cost of fuel used, steam pressure, condition of the weather, cost of oil and waste, and of wages for all the train men, and a column for the total cost while on the road per train mile, and another per car mile.

The total train expenses should be given in both ways, because there are two classes of trains, in one of which the number of cars is limited, as is the case in most passenger trains and local freight; the other class may consist of as many cars as the engine is capable of hauling, as is usually the case on our main lines, and on roads whose freight consists of some kind of minerals, as coal or ores. In the one case, the trains must be run, no matter how few the number of cars required, and therefore the cost should be estimated by the total expense *per train*. In the other case there is practically an unlimited number of cars, and the problem is, how to move them over the line at the least cost *per car*. It is of course true, that if the total cost to the company is regarded, that the cost of repairs to the road and to the rolling stock should be taken into consideration, but this the Committee think is beyond the range of their inquiries. By reference to the table it will be seen that in none of the experiments have they received full information regarding the various elements of expense involved in hauling trains.

Mr. Wells, of the Jeffersonville, Madison & Indianapolis Railroad, made a number of experiments "to determine the quantity of fuel consumed in doing the work in the ordinary way when no special effort was being made to economize, and under the conditions incident to the every-day events as they occur in the operations of a road, in which delays in waiting for trains or other causes are included." The first seven experiments were made with passenger trains, and the results, as far as reported, are given in the table. Engine 17, it will be seen from the table, was run with a single exhaust nozzle. This was removed after the seventh test, and to quote the language of

Mr. Wells, "double nozzles  $2\frac{3}{4}$  inches in diameter were substituted. No other changes or alterations whatever were made to the engine, or in the quality of the fuel used. The engine was run by the same man and under exactly the same circumstances as before." The results of the test under these conditions are given in the eighth experiment, of which Mr. Wells says: "From the result of these tests we find that with the double exhaust nozzles 39 pounds of coal did precisely the same work, both in train hauled and water evaporated, that 58 pounds did with the single nozzle. This marked difference is doubtless due to the increased draft produced by the smaller diameter of the double nozzles, which supplied to the coal in the grate the amount of oxygen necessary to induce a more perfect combustion."

After the eighth experiment "the valves in this engine—No. 17—were removed and new ones substituted, having 1 inch outside and  $\frac{1}{8}$  inch inside lap. A test was then made with the same trains, and under the same conditions." The results of this test are given in experiment nine. Mr. Wells says: "The difference due to the increased lap of the valve as shown in that test, is a saving of 1 pound of coal per mile compared with the previous test, and a decrease of water evaporated of 61 pounds per mile, and a decrease of 1.40 pounds of water evaporated to 1 pound of coal, but an *increase* of work done to 1 pound of coal consumed, equal to 1-10 of a ton conveyed 1 mile."

The tenth and eleventh experiments were made with a freight engine which had a single nozzle during the tenth and a double nozzle during the eleventh trial. Mr. Wells' comments on these two experiments are: "The difference in the results of these tests, due to the exhausts, and in favor of the double nozzle is shown to be a saving of 15.4 pounds of coal per mile, and a loss in water evaporated of 0.15 pounds to 1 pound of coal, but a gain in work done equal to the difference between conveying 4.85 tons 1 mile with the single nozzle and 6.03 tons 1 mile to 1 pound of coal when the double nozzle was used."

Experiment No. 12 was with a freight engine, No. 27. Experiments 13 and 14 were with engine No. 40, exactly similar in pattern and dimensions to No. 27. When the thirteenth experiment was made, engine No. 40 had just come out of the shop after having tubes taken out and boiler cleaned. "Previous to taking this engine

in the shop, and while the tubes were heavily coated with scale, and while more or less scale had accumulated on the crown sheet, a test was made in order to determine what effect scale and dirt had on the quantity of coal required in order to do a given amount of work as compared with a comparatively clean boiler. This boiler had been in use three years, and made a mileage of over 75,000 miles."

The results of the test are given in Experiment 14. Of this Mr. Wells says: "The extremely cold weather during the time this test was being made doubtless was one reason of the large consumption of fuel. If we ignore that, however, then the difference due to the heavy scale on the heating surfaces of the boiler is as 2.80 is to 5.52. In other words, 1 pound of coal consumed in a clean boiler will convey 5.52 tons 1 mile; while in one heavily coated with scale and dirt, only 2.80 tons can be conveyed the same distance."

Experiments 15, 16, and 17 give the results of ordinary working of passenger and freight engines on the St. Louis, Vandalia & Terre Haute Road.

Experiments 18, 19, and 20 were made by Mr. Boon, on the Fort Wayne Road, to determine the coal consumed and water evaporated in ordinary passenger service. A number of indicator diagrams were also sent with Mr. Boon's report, and which are submitted herewith.

Experiments 21, 22, 23, and 24 were made on the Connecticut River Road to determine the value of Mr. Gordon H. Nott's improvement of the fire box, which was applied to engine No. 15. Mr. Stearns, the Master Mechanic of this road, says: "In these experiments the performance of No. 15 shows a saving over that of No. 2 of 20.3 per cent. in one case and of 18.5 per cent. in the other."

An elaborate series of experiments were made on the Lake Shore & Michigan Southern Road last year to determine the value of various kinds of fuel. The Committee regret that these are too voluminous to give in a report like this. Only a recapitulation was possible, which is given in Experiments 25, 26, 27, 28, and 29. These are valuable chiefly in giving the cost of fuel per train mile and per car per mile.

Experiments 30 and 31 were made by Mr. Howard Fry on the Niagara Falls Branch of the Erie Road to try the effect of increasing the lap of the valve. In Experiment 30 the engine had 13-16 inch lap of valve and in Experiment 31 it had 1 inch. It will be



seen that with the smallest lap the consumption of fuel is very much larger than with 1 inch lap in the thirty-first experiment. Experiment 32 was made with one of Mr. Mason's single boiler double truck or Fairlie engines, and Experiment 33 was made with an ordinary passenger engine.

The Committee have also received from Mr. William Fuller, General Master Mechanic of the Atlantic & Great Western Railroad, a report of the performance of engine No. 302, operated by that company, and the engine Weston, operated by the inventor of the boiler which is known by the same name. Although not so stated in the report, it is inferred that engine 302 had a boiler of the ordinary construction. The reports of performance it was found difficult to tabulate, so they are submitted in full herewith for publication with the report.

Besides the experiments made which we have tabulated, Mr. Wells made an experiment, the report of which we give in his own language. "On making a test, which was continued for twelve hours, it was found that it required 25 pounds of coal per hour to keep up a steam pressure of 80 pounds per inch, in the boiler of engine No. 40, when it was clean and in good order and perfectly tight; the boiler had been lately covered with pine lagging and Russia iron jacket, the dampers to the ash pan were kept closed, and no steam was allowed to escape or leak out, nor was the engine moved during the twelve hours referred to, nor was there any water put into the boiler during that time, and at the end of the test but little difference in the water level could be noticed from that at the beginning. From this it would seem that 25 pounds of coal per hour is required to make good the heat lost by radiation alone, from a boiler of this size, containing 8,200 pounds of water, under the conditions stated above. At the time of the test the engine stood on a side track, and the temperature of the atmosphere averaged 50 degrees. There was no wind. The test was made March 14. At another time, the same month, a four-wheeled switching engine weighing 16 tons was kept under steam for ten consecutive hours, at an average pressure of 80 pounds; no steam was allowed to blow off, the dampers to ash pan were kept closed, but during the time the engine was run one-quarter of a mile to "pump-up," in order to make good the loss of water from the escape of steam through slight leakage at the

throttle and safety valves. In this case the consumption of coal was 32 pounds per hour.

Passenger engine No. 21, cylinders  $14 \times 22$ , drivers 5 feet diameter, weight of engine and tender (average) 49 tons, and of the ordinary eight-wheel pattern, running from Indianapolis to Jeffersonville empty, April 12, was run as follows: Time consumed in running 108 miles, four hours and fifty-five minutes; time consumed waiting at stations, one hour and five minutes; total, six hours; stops made, 6; average speed when running, 22 miles per hour; average steam pressure, 100 pounds; coal consumed per mile,  $18\frac{1}{2}$  pounds; water evaporated per mile, 109 pounds; water evaporated to 1 pound of coal, 5.91 pounds; water evaporated per minute while running, 40 pounds; tons of engine and tender conveyed 1 mile to 1 pound of coal, 2.60; heating surface of fire box, 77 feet; of tubes, 598 feet; total, 675 square feet; coal used, "Indiana Block Coal."

By measuring the wood it was found that ordinarily it required one-sixth of a cord to raise steam in a boiler to 80 and 100 pounds pressure, the boiler being cold at the time of beginning.

Mr. Hayes made experiments to determine the quantity of fuel consumed by a locomotive and tender alone, without any cars or train, of which we give his report as follows:

"On June 26 and 27, 1872, engine No. 131 ran from Chicago to Centralia, and used 6,427 pounds of coal; distance,  $252\frac{1}{2}$  miles; no train.

"On May 21, 1874, engine 31 ran from Chicago to Champaign, and consumed 2,689 pounds of coal; distance, 128 miles; no train.

"On July 6, 1874, engine 42 ran from Chicago to Champaign, 128 miles, and used 2,457 pounds of coal; no train. Engine 131 has 15 inch cylinders and wheels 5 feet diameter. Engine 31 has 15-inch cylinders and  $5\frac{1}{2}$  feet wheels. Engine 42 has 15-inch cylinders and 5 feet wheels. I think better results could have been obtained with engine 131."

Several tests were made by Mr. Wells with engine 35, working on the incline plane at Madison, the results of which are so interesting that we give his report in full. They were made April 9 and 10, "To determine the quantity of fuel consumed in doing a given amount of work, and the adhesion of the wheels to the rails, in proportion to the weight, which can be relied on under ordinary cir-

cumstances." This engine is what is called a tank engine: the cylinders are  $20\frac{1}{2} \times 24$  inches; steam ports,  $1\frac{1}{2} \times 18$  inches; valve,  $\frac{5}{8}$  outside and 1-16 inside lap, and  $4\frac{1}{2}$  inches throw. The wheels are all drivers, and consist of five pair, 44 inches in diameter; tires, steel; heating surface of fire box, 114 feet, and of tubes, 1,170 feet; total, 1,284 feet; average weight of engine with water and fuel, 54 tons.

The inclined plane is 6,940 feet in length, and the track is inclined 1 in  $16\frac{1}{2} = 320$  feet per mile. A train of eight loaded cars was taken up this grade as follows:

Weight of engine, 54 tons; weight of train, 154; total 208 tons; speed at starting on the incline, 2 miles per hour.

Left foot of plane at 3.40 P. M., steam pressure 140 pounds, cut off 19 inches.

Left foot of plane at 3.45 P. M., steam pressure 140 pounds, cut off 19 inches.

Left foot of plane at 3.50 P. M., steam pressure 143 pounds, cut off 19 inches.

Left foot of plane at 3.52 P. M., steam pressure 140 pounds, cut off 19 inches.

Arrived at top of plane at 3.53 P. M., steam pressure 130 pounds, cut off 19 inches.

Average speed, 6.06 miles per hour; fuel consumed, 0.56 cord of wood; time consumed in overcoming the elevation of 420 feet, 13 minutes.

The power requisite to overcome the force of gravity on this incline would be 1-16.5; the total weight of the train, or 25,212 pounds, and if we add eight pounds per ton for rolling and journal friction, we have then a total of 26,876 pounds. To overcome this an effective pressure of 122 pounds per square inch is required, which is equivalent to 434 horse power, or 14,324,908 foot-pounds per minute. The weight on the drivers available for adhesion on the incline is 1-16 $\frac{1}{2}$  less than the weight on a level track, and in this case would be 101,455 pounds.

Leaving off the power absorbed in rolling and journal friction of the engine, the adhesion of the drivers to the rails required to take this engine and train up the grade would be 25,286 pounds, or  $24\frac{3}{4}$  per cent. of their total weight on the rails. The rails were dry and there was no indications of slipping at any

time, and no sand was used; therefore we may conclude that the adhesion of a steel tire to a dry iron rail, at slow speeds, and on a straight track is, in round numbers, at least 25 per cent. of the weight on the rail. Another test was made April 10 with the regular passenger train. Weight of engine and train, 99 tons; speed at foot of inclined plane, 8 miles per hour, time consumed ascending or running 6,940 feet,  $5\frac{1}{2}$  minutes; average speed 14.6 miles per hour. Steam pressure in the boiler ranged from 127 to 135 pounds and averaged 132 pounds. Valves cut off steam to the cylinders at 12 inches of the stroke.

Power developed running on the incline was 15,107,000 foot-pounds per minute = 457 horse power; fuel consumed, 0.25 cord of wood.

#### TEST OF ENGINES, ATLANTIC & GREAT WESTERN RAILROAD.

##### ENGINE 302, RECAPITULATION.

	Trip No. 1.	Trip No. 2.	Trip No. 3.	Total.
Miles run.....	100	100	100	300
Actual running time.....	7 h. 54 m.	7 h. 32 m.	6 h. 50 m.	22 h. 25 m.
Average No. loaded cars hauled..	24	23 $\frac{1}{4}$	24	23 $\frac{1}{4}$
No. pounds of coal used.....	5,213	4,989	5,015	15,217
<i>Dynamometer:</i>				
Starting power.....	93,600	87,800	78,300	259,700
No. times taken.....	10	9	9	28
Average power between stations	93,500	95,500	96,000	285,000
No. times taken.....	15	15	15	45

##### ENGINE "WESTON," RECAPITULATION.

	Trip No. 1.	Trip No. 2.	Trip No. 3.	Total.
Miles run.....	100	116 $\frac{1}{2}$	100	316 $\frac{1}{2}$
Actual running time.....	9 h. 27 m.	8 h. 31 m.	7 h. 32 m.	25 h. 30 m.
Average No. loaded cars hauled..	23 $\frac{1}{4}$	23 $\frac{1}{4}$	24	23 $\frac{1}{4}$
No. pounds of coal used.....	4,642	6,000	5,410	16,052
<i>Dynamometer:</i>				
Starting power.....	75,700	167,600	125,300	368,600
No. times taken.....	8	15	12	35
Average power between stations	97,500	119,500	99,500	316,500
No. times taken.....	16	17	15	48

## COMPARISON.

	Engine 302.	En " We
Miles run per ton of coal.....	39.43	
Average miles per hour.....	13.48	
Average No. of cars hauled 1 mile per ton of coal.....	941.43	
Average pounds of coal used per mile ....	50.72	
General average of starting power at stations.....	9,275.00	10,
General average of power hauling trains between stations	6,333.33	6,

"The wood used in both tests was beech and oak, nearly dry the fuel left in the fire box, water in the boiler, and steam pressure corresponded with the same at the beginning, as nearly as could be determined."

The Committee submit their report as much, or perhaps more, than account of the information it *does not* contain as for that which its members have contributed. They have printed their table headings which indicate the kind of information that is desired, and which they think is needed to determine what engines are the most economical for various kinds of traffic. It will be seen, however, that the spaces under many of the headings are entirely blank, indicating that no information has been received relative to those topics. What they desire is, that in a future year they may be able to compute, as indicated in the last column, the cost of transporting cars and trains; and they have kept in mind, and hope to impart upon the members of the Association, that the final standard of estimating all kinds of railroad service is expressed in dollars and cents, and not in pounds and tons or in feet and inches.

W. N. FORNEY,  
WM. WOODCOCK

On motion, the report was accepted.

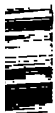
THE PRESIDENT—The subject is now open for discussion.

Mr. FORNEY, Railroad Gazette—In the table which we refer to I have a great number of headings, to show the sort of information that is needed. To determine economy in the coming year members should try to obtain that sort of information. If such facts could be accumulated through the efforts of the different members it would give a better idea of cost and economy in running locomotives than any thing else I know of.

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1	35	36	37	38	39	Number of Experiment.....
Boiler in Pounds—Driving Wheels in Pounds.....	Exhaust Nozzle—Single or Double.....	Diameter of Exhaust Noz- zle—Inches .....	Diameter of Inside Pipe in Smoke Stack—Inches .....	Date of Experiment.....	Kind of Service—Passenger or Freight .....	
2.84	.....	.....	.....	February 8-20, 1875.....	Passenger...	1
2.84	.....	.....	.....	January 20-30, 1875.....	"	2
2.84	.....	.....	.....	March 8-26 .....	"	3
2.84	Double..	2 1/2	.....	April 1-30, 1875.....	"	4
0.00	Single...	3 1/2	.....	Jan. 29 to Feb. 23, 1875.....	"	5
0.00	"	3 1/2	.....	.....	"	6
0.00	"	3 1/2	.....	.....	"	7
0.00	Double..	2 1/2	.....	February 5-22, 1875.....	"	8
0.00	"	2 1/2	.....	March 7-13, 1875.....	"	9
0.50	Single...	3 1/2	.....	March 20-29, 1875.....	Freight.....	10
0.50	Double..	2 1/2	.....	March 30 to April 8, 1875.....	"	11
4.90	"	2 1/2	.....	March 9-31 .....	"	12
4.90	"	2 1/2	.....	"	"	13
4.90	Single &	2 3/4 }	.....	January 7-16.....	"	14
0.63	Double..	3 1/2 }	15	.....	Passenger ...	15
0.00	Double..	2 1/2	16	.....	Freight .....	16
1.70	Single...	3 1/2	16	.....	"	17
.....	.....	.....	.....	October 27, 1875.....	Passenger ...	18
.....	.....	.....	.....	October 29, 1875 .....	"	19
.....	.....	.....	.....	October 31, 1875.....	"	20
.....	.....	.....	.....	Dec. 30, 1875, to Jan. 5, 1876....	Freight .....	21
.....	.....	.....	.....	" " " .....	"	22
.....	.....	.....	.....	" " " .....	"	23
.....	.....	.....	.....	" " " .....	"	24
.....	.....	.....	.....	November, 1875.....	"	25
.....	.....	.....	.....	" " .....	"	26
.....	.....	.....	.....	" " .....	"	27
.....	.....	.....	.....	" " .....	"	28
.....	.....	.....	.....	" " .....	"	29
.....	.....	.....	.....	June 23 to July 3, 1874.....	"	30
.....	.....	.....	.....	July 10-18, 1874.....	"	31
0.00	.....	.....	.....	June, 1874 .....	"	32
.....	.....	.....	.....	November, 1873.....	Passenger ...	33

engil



# TAL 7

	No. of Experiment.....	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
85	Total Train Expenses while on Road, per Mile Run.....																																	
84	Total Train Expenses while on Road, per Car, per Mile..																																	
83	Cost of Brakemen and Conductors .....																																	
82	Cost of Locomotive Runner and Fireman's Wages per Mile.....																																	
81	Cost of Waste, Bags, and Packing per Train per Mile.....																																	
80	Cost of Oil per Train Mile, Freight.....																																	
79	Quantity of Oil used for Engine, Train, and Signal Lights .....																																	
78	Cost of Oil per Train Mile, Passenger.....																																	
60	Cost of Fuel per Ton of 2,000 Pounds.....																																	
	Coal.....																																	

f scales.

half full of water and fuel.





Mr. FRY, Philadelphia & Erie Railroad—In the report just read a very considerable saving seems to have been made in double instead of single nozzles, and I would like to know the relative height of each.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—The height of the nozzles was the same; there is not more than half an inch difference. The saving of fuel I attribute to better draft. The single nozzle was  $3\frac{1}{2}$  inches in diameter; the double nozzle was  $2\frac{1}{4}$  inches in diameter. This produced a better draft, and enabled them to run with a thinner fire. I think that was the only difference.

Mr. EDDY, Boston & Albany Railroad—In regard to double and single exhaust pipes with the single nozzle on the exhaust of one cylinder, the valve on the opposite side, is just right to let the pressure go over into the other cylinder and acts against that piston, and there I think the saving is. I have had considerable experience in that line, and know of many others that have done the same. I think at one time there were not a dozen engines running into Boston with double exhaust pipes; I think at the present time there are few but what have the double nozzle.

Mr. FRY, Philadelphia & Erie Railroad—I believe that Mr. Eddy's explanation of the result of the double nozzle is correct, and I would like to ask Mr. Wells if the engine steamed as free as the other, and did he take notice whether there was any back pressure?

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—We did not make any diagrams in reference to back pressure. I noticed that the engines steamed more freely with the double than the single nozzle, on account of the better draft.

Mr. EDDY, Boston & Albany Railroad—I attribute better draft to the fact that each time the engine exhausted it went straight out of the nozzle. In the single nozzle it goes over into the other cylinder and fills that, and leaves a large chamber to exhaust into.

Mr. STRATTON, Pennsylvania Railroad—I have had occasion to take diagrams of engines having single and double exhaust nozzles, and taking diagrams with the single nozzle has demonstrated clearly that the effect is transmitted to the other cylinder. The diagram of the exhaust line, at the moment of exhaust, will show a back pressure in the other cylinder amounting, in some cases, to ten pounds to the square inch; and steam will remain there and cause back pressure, continuing to the end of the stroke, causing a great deal of compression previous to the admission. It is very evident that the substituting of double nozzles to such engines will almost completely remove the back pressure. The amount of lead is very plainly shown on the diagram, and shows the necessity of having it, and enabling it to take up the momentum of the moving parts. An excess of lead operates very much against an engine working at its full capacity. I have heard that a chemical analysis has been made of the gases at the top of the

smoke stack, and it has been shown that there is an excess of oxygen in the gases there, showing that there has been more air used through the grates than is actually necessary for combustion; so that it is not always a lack of air that is the difficulty in the fire box. That is the first that I have known of such an analysis being made at the smoke stack, and it would seem from that that there is always sufficient air to obtain perfect combustion.

Mr. FORNEY, Railroad Gazette—I can confirm what Mr. Stratton has said on the effect of the double nozzle. I have taken diagrams.

Mr. BROOKS, Brooks Locomotive Works—I would say that several years ago—I think in 1864—engines were running on the Erie Road with single nozzles. An experiment was made with a Tannton engine with a single nozzle; there was a square partition between the exhaust cores, a slight bridge across the bottom of the central nozzle, leaving the opening very large, which showed that the effect on the opposite cylinder at the moment of exhausting was highly detrimental. This experiment led to an entire exclusion of single nozzles on the Erie Road, except in the last twenty engines I have just constructed we had instructions to put in variable exhausts. We built six in this manner. We then had instructions to send out the next engine with double nozzles; but as soon as we got fairly at work we had notice to discontinue their use. This question of exhaust is a very important matter, as I have before remarked. It is really of a great deal more importance than is generally conceded in the proper working of an engine. The quality of the expulsion of the exhaust is what determines the quality of the inlet of the draft. It is the disturbance of this quality that does the business in this regard; it is more positive with the single pipe from the time it leaves its life of beginning. It has a great many turns to make, and the moment the line is let go there is nothing back of it, and there is nothing to help expel it; and when it is gone the disturbance is a very serious matter. I have never been so firmly convinced of that as within the last six months. When building those twenty engines with the variable exhausts we changed the exhaust core from five to six inches. The first pipes sent had a five-inch core; these pipes were put upon the engines, and after four or five had been sent it was discovered that there was a very marked difference; there was a square shoulder, and a departure from the core of the cylinder itself at the first joint of the exhaust pipe which made a disturbance. It was not because there was not room enough, but there was such a disturbance in the quality of the expulsion that it made a difference in the quality of the draft. Any disturbance that you have in curves you have from the time that exhaust leaves the cylinder until expelled from the nozzle. The minutest attention that can be paid to all these curve lines will add very materially to the quality of it and its draft.

THE PRESIDENT—The decision was to adjourn at one o'clock and meet in

the afternoon from two to five. Business of great importance will come before the Association.

At one o'clock the Convention adjourned to meet at two o'clock P. M.

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### AFTERNOON SESSION.

The Convention was called to order at two o'clock.

**THE PRESIDENT**—The discussion on locomotive tests is still in order.

**Mr. FORNEY, Railroad Gazette**—Before the report is laid on the table entirely I would like to get some expression of opinion with regard to that point that came up incidentally in reference to the relative economy of hauling heavy and light trains. On the Pennsylvania Road they have an unlimited number of cars to transport from here to Pittsburgh. Can you transport with powerful engines with ninety cars, or subdivide and take half that number of cars? When you come to take train expenses, the cost of fuel, oil, brakemen, I have been astonished to see what seemed to me the economy of hauling large trans. The other question of repair of roads and machinery comes in. In reference to the point of repairs in machinery I am requested to read a little extract from a paper I hold in my hand. It is from a report of one of the meetings held by the Chief Engineer and Road Masters of the Atlantic & Great Western Railroad, and the report referred to says:

"The following are the remarks of the different road masters of the subdivisions: Mr. Ryan said, 'They were the ruin of the fourth division.' Mr. McInarna, 'Where I keep up my track with one man to the mile, I would want two and a half men if the Mogul engines were used.' Mr. Burgess, 'I do not want them.' Mr. Bowen, 'I could not keep my track in line with them. I had them hauling gravel last summer, and could count every joint on the road.' Mr. Thompson, 'They were used on the Mahoning division until nearly all the iron was spoiled. I think they are the worst thing that can be put on the track.' Mr. Newham, 'They are very hard on track, and especially on curves.' Mr. Mulvey, 'I do not like to see them; would rather see freight trains running thirty miles an hour.' Mr. Callopy, 'I do not want them. They straighten out curves. After one of them passes you can see a straight piece in the curve.' Mr. Armstrong, 'I think the best place for them is on a side track; they are a great injury to the main track. I would rather have a full train with an ordinary engine go over the track than a Mogul engine without any train.' Mr. McInarna, 'It is impossible to keep curves in line with Mogul engines on the track.'"

I have read this at the request of Mr. Eddy. If the injury to the track is as great as indicated by this report, we will have to balance the expenses and find out whether we lose or gain more by these heavy engines. I hope the Master Mechanics will look into this next year and send in some information.

Mr. MORRIS SELLERS, of Chicago—I consider the report of the experiments that Mr. Dripps gave this Association as most valuable. It has demonstrated fully the friction of different engines, or those of different construction, in passing round a curve. The engine that has the least amount of friction is least destructive to the curves. I consider the result of these experiments gives a reply to the road masters in this report just read. I have some doubts as to the value of a report from a body of men who will say that a track is destroyed by a locomotive that has less weight per driving wheel and in which the friction is less, as is proved by the experiments. I have less confidence in that than I would have in my own judgment.

Mr. EDDY, Boston & Albany Railroad—I do not know where we are, whether we are discussing Mr. Dripps, or what. I trust you will bear with me if I make a few remarks.

THE PRESIDENT—The question is on locomotive tests.

Mr. EDDY, Boston & Albany Railroad—Mr. President, with all deference to Mr. Dripps, I submit that he has tried no experiment with a locomotive; he had no locomotive; it had no locomotion on it; it could neither haul itself nor a car; it was not a locomotive but simply a carriage. The locomotive with those driving wheels connected, and a train of wheels connected with it, which at each turn goes grinding and slipping along would be an entirely different thing from what Mr. Dripps had.

Mr. HUDSON, Rogers Locomotive Works—Without wishing to find fault or question at all the competency of Mr. Dripps to make experiments, I am not satisfied that his experiments clearly show the relative differences between the different classes of locomotives. One reason is they were not locomotives at the time, but simply carriages; but I am not informed as to whether those carriages were pushed or drawn over the road; I think that would make an important difference.

THE PRESIDENT—I think Mr. Fry said they were drawn over the curve.

Mr. HUDSON, Rogers Locomotive Works—If they were drawn I think then the result is different from what the friction would be if the locomotive were a propelling machine, therefore it is important that we should arrive at a correct knowledge of relative resistances. I have no preferences so far as one or the other class of locomotives is concerned; I believe all are adapted to special services, but I doubt whether either the Mogul or consolidation type is adapted to all classes of freight service.

Mr. FRY, Philadelphia & Erie Railroad—I think Mr. Forney has called our attention to a more important matter to decide next year in locomotive

tests, and that is the comparative cost of heavy and light trains. A part of the information we desire is the destructive effect upon the track of heavy engines of whatever type. If I understand Mr. Forney's plan, it is to bring before the Association the importance of collecting information on this matter; we can get very little at present. The remarks from the Road Masters of the Atlantic & Great Western Road are of no value; they give no data except in a general way. The engine itself was not specified in which the destructive effect might have resulted from imperfect construction of the engine or some other element not mentioned. It is not to be taken for granted that because these destroyed the track all engines would do the same. There are other engines of the same type which must have been in use for the past ten years, and if you can get the superintendent, or whoever is connected with a number of men who keep the track in repair after a given number of heavy engines, to make a report, it would be extremely valuable information, and should be incorporated in the report for next year. We may find out that in several departments we might save money; but it might cost more money in other respect, as by destroying the track, etc. I hope we may take the hint and see that the next committee on locomotive tests is supplied with fuller information on the effect of transportation in heavy and light trains.

Mr. MORRIS SELLERS, of Chicago—In referring to the matter which Mr. Forney has just read from the report of the Road Masters of the Atlantic & Great Western Road, I remember one class that they objected to, the Mogul engine, from the fact that they flattened the curve. One man says: I find a flat place in the curve; another, they destroy my track. Now, in regard to flattening the curve, my remarks were directly in reference to that. If these engines had flattened the curve it must have been from friction of the driving wheel; her long wheel base being a chord to the arc would have twisted the track out of line; Mr. Dripps' experiment shows there was less friction than with the ordinary eight-wheel engine, therefore I say the experiments of Mr. Dripps are of the most valuable character; she was not merely a wagon hauled around, she was a locomotive with all the attributes of a locomotive; the mere fact of having steam at each end of that piston had nothing to do with the friction around the curve. They are most valuable to us in that connection. I think a man with the intelligence of Mr. Dripps, and the ability he has displayed in presenting the report of those experiments, is entitled to our highest consideration, and we should receive his report at its due value; and, as I said before, although she was merely hauled she had every attribute of a locomotive.

Mr. EDDY, Boston & Albany Railroad—I submit to this Association that Mr. Dripps did not have a locomotive; I would like to know what a locomotive is if it has not the means of locomotion within itself. With regard to the track, Mr. Fry speaks of the effect of certain locomotives being destructive to the track; I have never seen a track master that did not tell the

same story in regard to Mogul engines; go and ask the best section man you can find and see what he will say.

Mr. FRY, Philadelphia & Erie Railroad—I asked a supervisor of track what the effect of running very heavy engines of the consolidation type was over his track for the last six years. He said he had the same number of men to the mile as he always had; he thought the steel was wearing rather faster; it had lasted for six years and probably longer; he could not say how much faster, but thought it was somewhat faster. The track was not torn all to pieces, nor were the curves flattened or straightened out; the value of the report of the Committee on Tests is that it gives us so many facts for our consideration. It would be absurd for us to pin our faith upon Mr. Dripps' experiments; but it is the accumulation of evidence which will enable us to ascertain what results are obtained from certain measures; but if out of a dozen experiments only two or three agree with Mr. Dripps, and nine or ten demonstrate that opposite results were to be obtained, of course we should say that Mr. Dripps was mistaken. We hope now to get an accumulation of evidence so that the Committee can obtain more certain results.

Mr. SETCHEL, Little Miami Railroad—I agree with Mr. Eddy that pushing a locomotive around a curve differs widely from running round with steam. Both classes of engines however were operated upon in precisely the same way, and it seems to me that for the purpose of obtaining the difference in the amount of friction, the experiment was all that you could make; and if steam in one engine would make a difference we might expect the same difference would be made in the other engine. It was a legitimate way in determining the amount of friction in the two classes of engines; both were drawn around the curve cold, without steam.

Mr. EDDY, Boston & Albany Railroad—I suppose that it is well known to every Master Mechanic that you connect to what you call the main driving wheels another pair by connecting rods. You run the parallel rods as tight as you can and there will be a decidedly perceptible slip between the front and back wheel. If you had another pair there would be just as much if not more; suppose you had a dozen. I have seen and run on our road six-wheel connected engines, made by Baldwin thirty years or more ago; I have seen these back wheels worn half an inch smaller than the front, and the middle ones half way between; suppose Mr. Dripps had been hauling these engines around a curve, would there have been the same slipping of the wheels as if they had steamed around? Nobody thinks anything of the kind; it makes all the difference in the world, and it seems to me it is so plain that it does not require any argument that when he hitched on the engines he had nothing more than a carriage; those connections were entirely useless; they do not come into play as when the engine is working.

Mr. LAUDER, Northern New Hampshire Railroad—I move that the discussion on this subject be closed.

The motion was carried.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—I have a resolution here which I desire to offer; the reasons may be apparent:

**Amendment to Constitution.**

*Resolved*, That members of this Association who have been in good standing for a period of not less than five years, and who through age or other cause cease to be actively engaged in the mechanical departments of railroad service, may, upon the unanimous vote of the Association, be elected honorary members, having all the privileges of regular members except that of voting.

I would offer this as an amendment to our Constitution, and make a motion to that effect.

Mr. WILDER, Erie Railroad—I second the motion.

Mr. FORNEY, Railroad Gazette—It seems to me that the resolution is a little vague in regard to the payment of dues. It should have been stated whether honorary members are to pay their dues or not.

Mr. WILDER, Erie Railroad—If a person pays dues I should say he was an active member; in all societies if a man who is an active member is made an honorary member his dues are remitted.

Mr. FORNEY, Railroad Gazette—My only object is to make it sure.

THE PRESIDENT—I think the Constitution calls for no dues at all only what are stated at each meeting.

THE SECRETARY—The Constitution says: "All members of the Association shall be liable for dues."

THE PRESIDENT—Perhaps it would be better to have it sure.

Mr. FORNEY, Railroad Gazette—I would move as an amendment, to add that the dues be remitted.

THE PRESIDENT—It will certainly be understood that it will be without dues.

Mr. FORNEY, Railroad Gazette—Suppose that a member of the Association should withdraw and enter some other branch of business, would that man's dues be remitted or not in case he became an honorary member?

THE PRESIDENT—I should certainly decide that if he became an honorary member he would not be subject to dues. We have a clause in the Constitution which says that he still continues a member if he pays his dues, but if we vote him an honorary member, it decides his dues to be remitted. That is my opinion, though I am willing to yield to higher authority.

Mr. CHAPMAN, Cleveland & Pittsburgh Railroad—I would suggest that, in place of that, we make it Article VI, making the present Article VI Article VII.

Mr. WELLS, Erie Railroad—I accept Mr. Forney's amendment.

The resolution, as amended, was adopted.



**THE PRESIDENT**—Our Constitution provides for a certain number of associate members; there has been laid on my desk the following:

“The undersigned, members of the Association, would respectfully present the name of P. H. Dudley as a suitable person to become an associate member of the Association.

“Signed, N. E. CHAPMAN,  
S. J. HAYES,  
JAMES SEDGLEY.”

The Constitution provides that it shall be referred to a committee, which shall report to the Association concerning the fitness of the person for such membership. I will appoint Messrs. Philbrick, Robinson, and Warren as such committee.

The report of the Committee to suggest the next place of meeting is now ready.

**THE SECRETARY**—“The Committee to whom was referred the question of the place of our next annual meeting would respectfully report the following places: Richmond, Va.; Cincinnati, Ohio; St. Louis, Mo.”

**Mr. CLARK**, Lehigh Valley Railroad—I move that New York be added to the list.

The motion was agreed to.

**Mr. HAYES**, Illinois Central Railroad—In order to save time, as we have considerable business on hand, I move that we take the vote standing, first naming one place and then another, and see which gets the majority.

The motion was agreed to, and the result of the vote was as follows: Richmond, 9; St. Louis, 23; Cincinnati, 5; New York, 13.

**Mr. LEWIS**—I live within hailing distance of St. Louis, and I have no doubt that city would feel highly honored by our meeting there. She has no representative here. For my part, I would vote for St. Louis, as we have never been there.

**Mr. MORRIS SELLERS**, of Chicago—I move that we take the vote on St. Louis and New York.

This was agreed to, and the vote resulted as follows: St. Louis, 40; New York, 13.

**THE PRESIDENT**—The vote stands that our next annual meeting will be at St. Louis, Mo. The next business in order is the report of the Committee on Correspondence. Mr. Wells is the Chairman of that Committee.

Mr. Wells read the following:

“**R. HILL**, Esq., *Master Mechanic Camden & Atlantic Railway Co.*”

“I desire that you will extend to the members of the Master Mechanics' Association an invitation to visit Atlantic City, and, if

accepted, arrange for a meeting between a committee and myself to arrange details.

Signed,

"F. A. LISTER, *Sup't.*"

Mr. MORRIS SELLERS, of Chicago—I move that the communication be received, and the thanks of the Association be extended to Mr. Lister for his kind invitation.

The motion was agreed to.

### Resolution of Thanks to Franklin Institute.

*To the American Railway Master Mechanics' Association :*

GENTLEMEN—Your Committee on Correspondence recommend that the thanks of the Association be tendered the Franklin Institute for their kindness in giving to us the use of their hall, as tendered in the letter of Mr. Knight, Secretary, to Mr. Coleman Sellers, and that the Secretary be requested to notify the Franklin Institute of the same.

We also recommend that the letter of John G. Thompson, Railroad Commissioner of the State of Ohio, to the Secretary of this Association be filed, and that the Secretary acknowledge the receipt of the same.

R. WELLS,  
J. SEDGLEY,  
F. M. WILDER, } *Committee.*

The resolution was adopted.

THE PRESIDENT—I have received the following communication :

PHILADELPHIA, May 17, 1876.

H. M. BRITTON, *Pres't American Railway Master Mechanics' Association :*

MY DEAR SIR—Unable to take an active part as a member of the "American Railway Master Mechanics' Association," I hereby tender my resignation.

With my warmest wishes for the welfare of the Association,

I am, very truly, yours,

ISAAC DRIPPS.

Mr. WELLS, Jeffersonville, Madison & Indianapolis Railroad—I move the resignation be received, and that Mr. Dripps be unanimously elected an honorary member of this Association.

Mr. EDDY, Boston & Albany Railroad—I second the motion.

The motion was then agreed to.

THE PRESIDENT—The next business in order is the election of officers. I will appoint as tellers for the election—

Mr. SEDGELY, Lake Shore & Michigan Southern Railroad—I move that we postpone the election of officers for one year.

Mr. MORRIS SELLERS, of Chicago—I offer as an amendment that we elect the present officers of this Association by acclamation.

THE PRESIDENT—Our Constitution requires that the officers shall be elected by ballot.

Mr. ROBINSON, of Canada—It would be more proper for some active person on some railroad to take my place as one of the officers. I do not feel comfortable in keeping a position which I think belongs to some person actively engaged. I would like to see one of the newer members take my place.

THE PRESIDENT—So I think, that the presiding officer should be in the ranks of the Master Mechanics. Having been with the Association from the start, and your President from the first meeting, I think it right and proper that some person—a Master Mechanic—should be your President, but, as the motion is before the Convention, it is right and proper that I should put it to vote. The motion is that the election of officers be postponed for one year.

The motion, as stated, was agreed to.

THE PRESIDENT—The next business in order will be the report of the Committee on Assessments, but as they are not ready to report we will proceed to the election of associate members. The name of P. H. Dudley, recommended as an associate member, has been approved by Messrs. Philbrick, Warren, and Robinson. The Constitution provides that the number of associate members shall not exceed twenty, This is stated in Article IV, Section 2, which is as follows:

“Civil and mechanical engineers, and others, whose qualifications and experience might be valuable to the Association, may become associate members by being recommended by three active members. Their names shall then be referred to a committee, which shall report to the Association on their fitness for such membership. Applicants to be elected by ballot at any regular meeting of the Association; and five dissenting votes shall reject. The number of the associate members shall not exceed twenty. The associate members shall be entitled to all the privileges of active members except that of voting.”

We have twelve associate members at this time. Mr. Dudley was recommended by Messrs. Chapman, Hayes, and Sedgley. I will appoint as tellers Messrs. Barrett and Taylor.

The vote being taken, Mr. Dudley was declared unanimously elected.

**THE PRESIDENT**—One thing has slipped my attention, and that is the report of the Committee on Subjects for next year.

**Mr. WILDER, Erie Railway**—I move that the committee having in charge the various subjects for discussion for the ensuing year be requested to hand in their subjects at least one month before the meeting, and have them printed and presented for the use of the members.

**Mr. ROBINSON, of Canada**—What do we gain?

**Mr. WILDER, Erie Railway**—We gain the time taken up by reading the report. Persons who are not here when it is read do not hear the report, and have no means of knowing its subject matter.

**Mr. ROBINSON, of Canada**—If we have not the reports in our hands until the day of the meeting, that would be impossible to make this motion effective. I think an amendment should be offered that, after the papers are printed, they should be sent to the members, at their homes, at least a week before the annual meeting.

**Mr. WILDER, Erie Railway**—I have no objection to that if it will bring the reports of the committee into the hands of the members before they come here.

**THE PRESIDENT**—If I understand Mr. Wilder, that he means that the printed report should be in the hands of the members before the day of the meeting, I would say to Mr. Wilder, that it would be an impossibility for the Secretary to do it. To prepare the annual report is very close work for the Secretary. The manuscript each year has to be read over and prepared for the printer, and it takes three months to do it. A great deal of the matter is not prepared; and the result of such a motion would be that at our next meeting we would be minus any reports. If you had been on the Committee for Printing you would understand why it would be impossible to have these reports printed in advance. It costs about seven hundred dollars a year to print this book. A great deal of it is in tabular shape.

**Mr. WILDER, Erie Railway**—If the Secretary has this printing done before the meeting it need not be lost. All this matter that has been put in type could be used again in printing the annual report.

**THE PRESIDENT**—We can only have sixteen pages in print at once. We only have these sixteen pages before we read the proof, and when that has been corrected the stereotype plate is made, and the type is used over again. To set up all these reports, and keep them in type until the printing of the annual report, would take a large amount of type, and no printing establishment would do this. I merely make these statements to show that it would be impracticable.

**THE SECRETARY**—It was suggested at Chicago that that course should be pursued, and the Printing Committee, with the Secretary, called on Messrs. Wilstach, Baldwin & Co., who said they could not give the exact figures, but that it would be very expensive to print the reports and hold them in type, and the idea was abandoned by the Printing Committee. And then again, if the reports are not sent in early this plan could not be carried out. I succeeded in getting but three reports from the committees before leaving home; and that is the case usually. We can not get the reports in in season.

**Mr. WILDER, Erie Railway**—My resolution was to get the reports in at least one month before the meeting of the Association; I will withdraw it.

**Mr. FORNEY, Railroad Gazette**—It would not be well to adjourn without having some subjects to report for discussion next year.

**THE PRESIDENT**—I said the Committee on Subjects would be called upon to report. Is their report now ready?

**Mr. FORNEY, Railroad Gazette**, presented the report.

### **Report of Committee on Subjects.**

*To the American Railway Master Mechanics' Association:*

**GENTLEMEN**—The Committee appointed to select subjects for consideration at the next annual meeting respectfully recommend the following:

1. Construction of Locomotive Frames and Braces: this committee to report the best manner of constructing these parts and of attaching them to the boiler.

2. Slide Valves and Valve Gearing: this committee to report the best form and proportion of valves, steam ports, valve gear, and the functions which they should fulfill in the distribution of steam in locomotive cylinders. ,

3. Locomotive Boilers: this committee to report the best material, method, form, and proportion of construction of locomotive boilers, and the best manner of promoting combustion, especially with reference to the supply of air, the quantity which should be furnished, and the best appliance for admitting it to the fire for each kind of fuel.

4. Feed Water, the best point in the boiler to introduce it, and the cause and prevention of incrustation.

5. Locomotive Tests: the committee to request members to make experimental tests to show the performance of locomotives, and to report to this Association.

6. Engine and Tender Trucks, the best form of construction adapted for different classes of engines.

7. Lubricants: this committee to report the experience of members, indicating which are the best and most economical lubricants for different parts of locomotives and the means of applying them.

The report was accepted.

Mr. WILDER, Erie Railway—I move that the compensation for the Secretary be fixed at the same amount as for last year.

The motion was agreed to.

Mr. LAUDER, Northern New Hampshire Railroad—I have not time to make a written report from the Committee on Assessments, but I make the statement that I have collected the dues—ten dollars apiece—from sixty members, amounting to six hundred dollars.

Mr. ROBINSON, of Canada—I have been requested to bring before the attention of this Convention the advantage said to be gained by setting apart a number of minutes each day to answer technical questions belonging to our particular part of the railroad service. I would suggest that half an hour might be set apart every day to hear replies from every-body who would be willing to answer questions that might be laid on the Chairman's table.

Mr. WOODCOCK, New Jersey Central Railroad—I move that a vote of thanks be offered the press of Philadelphia for the reports of the proceedings of this Convention.

The motion was agreed to.

Mr. MORRIS SELLERS, of Chicago—I offer a resolution of thanks to the officers of this Association for the gentlemanly and able manner in which they have conducted the business of the Association for the past year.

Mr. FORNEY, Railroad Gazette—I move, as an amendment, the word faithful be added.

Mr. MORRIS SELLERS, of Chicago—That is entirely superfluous. Those who know the officers know they have been faithful.

The resolution was adopted.

THE PRESIDENT—I would like to call the attention of the members to the fact that it has been stated by every committee, that they have not received the number of answers to the questions contained in their circulars that they feel they have a right to receive; to many of the questions they received only ten or fifteen replies, twenty I think was the highest number. I think we all should feel that to keep up the reputation of this Association, and get out the information desired from various roads, that we have a right to expect these replies. Without these answers they can not compile their reports intelligently; it would take but a short time if each member will write answers to these questions presented by the Committees; they are all prepared

so that a very few words will answer them. If the questions can not be answered fully, let each answer as much as he can; give the committee all the information possible, that they may make as intelligent and thorough report as possible. We had a report yesterday which was so thorough that a vote of thanks was given to Mr. Wells; I was glad to hear that vote of thanks; only think of the amount of work required to compile that report from the mass of matter received from the members. I wish to impress upon the minds of every member the necessity of writing answers to these questions, and I would ask the committees to send their reports to the Secretary so that he can have time to read them over and read them intelligently at the meeting.

On motion of Mr. Woodcock the Convention then adjourned.

*Committees and Subjects for Discussion at the Tenth  
Annual Convention.*

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## 1

**Constructon of Locomotive Frames and Bracings.**

This Committee to Report the Best Manner of Constructing these Parts  
and of Attaching them to the Boiler:

J. M. BOON, Pittsburgh, Fort Wayne & Chicago;

F. M. WILDER, Erie;

E. H. WILLIAMS, Baldwin Locomotive Works;

A. MITCHELL, Western Division Lehigh Valley.

## 2

**Slide Valves and Valve Gearing.**

This Committee to Report the Best Form and Proportion of Valves, Steam  
Ports, Valve Gear, and the Functions which they should Fulfill in the Dis-  
tribution of Steam in Locomotive Cylinders:

J. N. LAUDER, Northern New Hampshire;

W. S. HUDSON, Rogers Locomotive Works;

F. A. WAITE, Boston & Maine.

## 3

**Locomotive Boilers.**

This Committee to Report the Best Material, Method, Form, and Propo-  
sition of Construction of Locomotive Boilers, and the Best Means of Promot-  
ing Combustion, especially with Reference to the Supply of Air, the Quan-  
tity which should be Furnished, and the Best Appliance for Admitting it  
to the Fire for each Kind of Fuel:

R. WELLS, Jeffersonville, Madison & Indianapolis;

C. R. PEDDLE, Terre Haute & Indianapolis;

S. J. HAYES, Illinois Central;

JACOB JOHANN, Toledo, Wabash & Western;

N. E. CHAPMAN, Cleveland & Pittsburgh.



**Feed Water.**

This Committee to Report the Best Point in the Boiler to Introduce it, and the Cause and Prevention of Incrustation:

E. T. JEFFERY, Illinois Central;

H. L. COOPER, Indianapolis, Bloomington & Western;

J. C. WILLS, Toledo, Wabash & Western.

**Locomotive Tests.**

This Committee Request Members to make Experimental Tests to Show the Performance of Locomotives and to Report the Results to the Association:

W. WOODCOCK, Central of New Jersey;

S. A. HODGMAN, Philadelphia, Wilmington & Baltimore;

DAVID CLARK, Lehigh Valley.

**Engine and Tender Trucks.**

This Committee to Report the Best Form of Construction Adopted for Different Classes of Engines:

PETER CLARKE, Northern of Canada;

W. A. ROBINSON, of Canada;

A. GOULD, New York Central & Hudson River.

**Lubricants.**

The Committee to Report the Experience of Members Indicating which are the Best and Most Economical Lubricants for Different Parts of Locomotives and the Means of Applying Them:

JAMES SEDGLEY, Lake Shore & Michigan Southern;

WM. FULLER, Atlantic & Great Western;

HOWARD FRY, Philadelphia & Erie.

**Trustees Boston Fund, Printing and General Supervisory  
Committee.**

H. M. BRITTON, New York & New England;

N. E. CHAPMAN, Cleveland & Pittsburgh;

W. A. ROBINSON, of Canada;

S. J. HAYES, Illinois Central;

J. H. SETCHEL, Little Miami.

**Committee on Arrangements for Tenth Annual Convention.**

JOHN HEWITT, Atlantic & Pacific.

O. A. HAYNES, St. Louis & Iron Mountain;

A. J. SANBORN, Indianapolis & St. Louis.

## CONSTITUTION

AS AMENDED AT THE SIXTH ANNUAL MEETING, BALTIMORE, MAY 13, 1873.

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### PREAMBLE.

WE, the undersigned, Railway Master Mechanics, believe that the interests of the Companies by whom we are employed may be advanced by the organization of an Association which shall enable us to exchange information upon the many important questions connected with our business. To this end do we establish the following

## CONSTITUTION.

### ARTICLE I.

SECTION 1. The name and style of this Association shall be the AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.

### ARTICLE II.

SEC. 1. The officers of the Association shall be a President, a First and Second Vice-President, a Secretary, and a Treasurer.

SEC. 2. The above-named officers shall be elected separately, by ballot, at a regular meeting, and a majority of all votes cast shall be necessary to a choice.

SEC. 3. The officers shall be elected for a term of one year, but in the event of the election being postponed shall continue in office until their successors shall be elected.

SEC. 4. Two tellers shall be appointed by the President to conduct the election and report the result.

### ARTICLE III.

SEC. 1. It shall be the duty of the President to preside in the usual manner at all the meetings of the Association, and approve all bills against the Association for payment by the Treasurer.

SEC. 2. It shall be the duty of the Vice-Presidents, according to rank, to perform the duties of the President in his absence from the meetings of the Association.

SEC. 3. In case of the absence of both President and Vice-Presidents, the members present shall elect a President *pro tempore*.

SEC. 4. It shall be the duty of the Secretary to keep a full and correct record of all transactions at the meetings of the Association; to keep a record of the names and places of residence of all members of the Association, and the name of the road they each represent; to receive and keep an account of all money paid to the Association, and at the close of each meeting deliver the same to the Treasurer, taking his receipt for the amount; to receive from the Treasurer all paid bills, giving him a receipted statement of the same.

SEC. 5. It shall be the duty of the Treasurer to receive all money from the Secretary belonging to the Association; to receive all bills against the Association, and pay the same, after having the approval of the President; to deliver all paid bills to the Secretary at the close of each meeting, taking a receipted statement of the same; to keep an accurate book account of all transactions pertaining to his office.

#### ARTICLE IV.

SEC. 1. The following persons may become members of the Association by signing the Constitution, or authorizing the President or Secretary of the Association to sign for them, and pay the initiation fee of one dollar. Any person having charge of the Mechanical Department of a Railway known as "Superintendents," or "Master Mechanics," or "General Foremen," the names of the latter being presented by their superior officers for membership. Also, two Mechanical Engineers or the representative of each Locomotive Establishment in America.

SEC. 2. Civil and Mechanical Engineers and others whose qualifications and experience might be valuable to the Association may become Associate Members by being recommended by three active members. Their names shall then be referred to a committee, which shall report to the Association on their fitness for such membership. Applicants to be elected by ballot at any regular meeting of the Association, and five dissenting votes shall reject. The number of Associate Members shall not exceed twenty. Associate Members shall be entitled to all the privileges of active members excepting that of voting.

SEC. 3. Any person who has been or may be duly qualified, and signs, or causes to be signed, the Constitution, as member of the Association, remains as such until his resignation may be voluntarily tendered.

SEC. 4. All members of the Association will be liable for such dues as may be necessary to assess to defray the expenses of the Association, and any member who shall be two years in arrears for annual dues shall have his name stricken from the roll, and be duly notified of the same by the Secretary.

## ARTICLE V.

SEC. 1. The regular meeting of the Association shall be held annually on the second Tuesday in May.

SEC. 2. Regular meetings shall be held at such place as may be determined upon by a majority of the members present at the previous meeting.

SEC. 3. An adjourned meeting may be held at any time and place that a majority of the members present at any meeting may elect.

SEC. 4. The regular hours of sessions shall be from 9 o'clock A. M. to 2 o'clock P. M.

SEC. 5. During the business sessions no communications shall be received or acted upon other than those pertaining to the business of the Association.

## ARTICLE VI.

SEC. 1. This Constitution may be amended at any regular meeting of the Association by two-thirds vote of the members present.

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*Resolution passed at the Sixth Annual Meeting, Baltimore, May, 1873.*

*Resolved*, That no expense shall be incurred by committees except by the unanimous consent of the General Supervisory Committee, given in writing to the chairman of said committee, stating the amount to be expended.

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*Resolution on Boston Fund.*

*Resolved*, That the Boston Fund, amounting now, with accrued interest, to \$3,620, be invested in Government securities to be selected by the duly appointed Trustees, and not to be disturbed for the purpose of expenditure unless authorized by the majority of members present in open convention, and then only after due notice of a motion to expend the same has been given at the session immediately preceding; and that the interest accumulating shall every year be invested in the same manner as the principal, and a full account of the same be duly reported with other financial statements.

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*Resolution Adopted at the Ninth Annual Meeting.*

*Resolved*, That members of the Association who have been in good standing for a period of not less than five years, and who through age or other cause cease to be actively engaged in the mechanical departments of railroad service, may, upon the unanimous vote of the Association, be elected "Honorary Members," who shall have their dues remitted and be entitled to all the privileges of regular members except that of voting.

# **NAMES AND ADDRESS OF MEMBERS.**

NAME.	ROAD.	ADDRESS.
Anderson, H.....		156 Lake st., Chicago.
Anderson, J. H.....	N. Y. B. & P. Rd.....	Providence, R. I.
Anderson, R. H.....	G. & C. Rd.....	Helena, S. C.
Alden, H. A.....	C. C. & B. & O. Rd.....	Brockville, Ont.
Britton, H. M.....	N. Y. & N. E. Rd. ....	Boston, Mass.
Boon, J. M.....	P. Ft. W. & C. Rd .....	Fort Wayne, Ind.
Baer, R. B.....		Texas Ave. & Travis St. Houston, Tex.
Bushnell, R. W.....	B. C. R. & M. Rd.....	Cedar Rapids, Iowa.
Brastow, L. C.....	L. & S. Rd.....	Ashley, Pa.
Brown, H. L.....		New Lebanon, N. Y.
Blackall, R. C.....	A. & S. Rd.....	Albany, N. Y.
Boyden, G. E.....	B. H. & E. Rd.....	Boston, Mass.
Brooks, H. G.....	Brooks Locomotive Works.....	Dunkirk, N. Y.
Britton, A. W..	Late C. & W. V. Rd.....	Harrison, O.
Burford, H. N.....	M. & C. Rd.....	Memphis, Tenn.
Blackburn, V.....	Erie Rd.....	Jersey City, N. J.
Brewer, S. E.....	N. Y. N. H. & H. Rd..	Hartford, Conn.
Bookhammer, H. J....	O. C. & A. R. Rd.....	Oil City, Pa.
Barrett, J. Davis.....	G. T. Rd.....	Montreal, Canada.
Black, John.....	D. & M. Rd.....	Lima, Ohio.
Chapman, J. W.....	Erie Rd.....	Hornellsville, N. Y.
Cooper, W. E.....		Dunkirk, N. Y.
Chapman, N. E.....	C. & P. Rd.....	Cleveland, Ohio.
Cummings, S. M.....	P. Ft. W. & C. Rd.....	Allegheny, Pa.
Coolidge, G. A.....	F. Rd.....	Charlestown, Mass.
Clark, David.....	L. V. Rd.....	Hazleton, Pa.
Cooper, H. L.....	I. B. & W. Rd.....	Urbana, Ill.
Church, Foster.....	T. & B. Rd.....	Troy, N. Y.
Collings, E.....	C. & A. Rd.....	Camden, N. J.
Colburn, R.....	N. & W. Rd.....	Norwich, Conn.
Cook, James.....	Danforth & Cook's Locomotive and Manufacturing Co.	

NAME.	ROAD.	ADDRESS.
Cushing, Geo.....	M. K. & T. Rd.....	Sedalia, Mo.
Coon, G. F.....	M. R. Rd.....	Hancock, Mich.
Cory, Charles H.....	C. & V. Rd.....	Carmi, Ill.
Curtis, Robert.....	P. C. & St. L. Rd.....	Columbus, Ohio.
Crockett, John F.....	B. L. & N. Rd.....	Boston, Mass.
Clark, Peter.....	N. Rd. of Canada.....	Toronto, Canada.
Child, F. D.....	Hinkley Locomotive Works.....	Boston, Mass.
Cascaddin, R. O.....	C. R. I. & Pac. Rd.....	Trenton, Mo.
Cook, Leo L.....	B. & A. Rd.....	Brunswick, Ga.
DeClercq, A. H.....	C. D. & V. Rd.....	Danville, Texas.
Devine, J. F.....	W. & W. Rd.....	Wilmington, N. C.
Duncan, Wm.....		Worcester, Mass.
Dohoney, R. V.....		McMechen St., Baltimore, Md.
Dripps, W. A.....		3405 Walnut st., Philadelphia, Pa.
Eddy, Wilson.....	B. & A. Rd.....	Springfield, Mass.
Elliott, Henry.....	Late O. & M. Rd.....	East St. Louis, Mo.
Edams, J. B.....	I. C. Rd.....	Amboy, Ill.
Eastman, J. U.....	N. & C. Rd.....	Nashville, Tenn.
Ellis, J. C.....	Schenectady Locomotive Works.....	Schenectady, N. Y.
Eastman, C. L.....	C. Rd.....	Concord, N. H.
Elder, Jos.....	R. R. I. & St. L. Rd.....	Beardstown, Ill.
Ellis, W. H.....	P. & R. Rd.....	Catawissa, Pa.
Foss, J. M.....	C. V. Rd.....	St. Albans, Vt.
Fry, Howard.....	P. & E. Rd.....	Williamsport, Pa.
Flynn, J. H.....	W. & A. Rd.....	Atlanta, Ga.
Fuller, Wm.....	A. & G. W. Rd.....	Meadville, Pa.
Fellows, Chas.....	M. & C. Rd.....	Elyria, Ohio.
Faries, H. V.....	A. T. & S. F. Rd.....	Topeka, Kansas.
Finlay, L.....	C. & F. Rd.....	Little Rock, Ark.
Fields, W. A.....	P. & O. Rd.....	Portland, Maine.
Funk, J. S.....	N. C. Rd.....	Marysville, Pa.
Foster, W. L.....	P. & E. Rd.....	Renovo, Pa.
Foster, W. A.....	W. & M. Div. F. Rd.....	Fitchburg, Mass.
Gibbs, E. B.....		Carondalet, Mo.
Graham, Chas.....	L. & B. Rd.....	Kingston, Pa.
Glass, G. W.....	A. V. Rd.....	Pittsburgh, Pa.
Garfield, E.....	H. P. & F. Rd.....	Hartford, Conn.
Garrett, H. D.....	P. Rd.....	West Philadelphia.
Gorman, T. G.....	M. K. & T. Rd.....	Springfield, Ill.

NAME.	ROAD.	ADDRESS.
Grant, R. D.....	A. & P. & M. Rd.....	St. Louis, Mo.
Griggs, W. H.....	N. Y. & O. M. Rd.....	Oswego, N. Y.
Griggs, Albert.....	W. & N. Rd.....	Worcester, Mass.
Granger, W. E.....	A. & N. E. Rd.....	Springfield, Mass.
Gould, A.....	N. Y. C. & H. R. Rd..	Rochester, N. Y.
Gould, F.....		Middletown, Orange Co., N. Y.
Gilbert, W. G.....	P. & St. L. Rd.....	Portland, Oregon.
Hipple, W. H.....	Late T. & P. Rd.....	Marshall, Texas.
Hayes, S. J.....	Ill. Cent. Rd.....	Chicago, Ill.
Hill, E. O.....	Erie Rd.....	New York City.
Holloway, J. W.....	C. Mt. V. & C. Rd.....	Akron, Ohio.
Ham, C. T.....	Buffalo Steam Gauge Co.....	Buffalo, N. Y.
Hull, A. S.....	C. V. Rd.....	Chambersburg, Pa.
Hudson, W. S.....	Rogers Locomotive Works.....	Paterson, N. J.
Hewitt, John.....	A. & P. Rd.....	St. Louis, Mo.
Haynes, O. A.....	St. L. & I. M. Rd.....	Carondalet, Mo.
Healy, B. W.....	Rhode Island Locom'v'e Works.....	Providence, R. I.
Hollister, C. W.....	Valley Rd.....	Hartford, Conn.
Hubbard, J. G.....	Erie Rd.....	Buffalo, N. Y.
Hodgman, S. A.....	P. W. & B. Rd.....	Wilmington, Del.
Hain, F. K.....	Erie Rd.....	Susquehanna, Pa.
Hanglin, J. A.....	Texas Pacific Rd.....	Marshall, Texas.
Hill, Rufus.....	C. & A. Rd.....	Camden, N. J.
Haggett, J. C.....	D. A. V. & P. Rd.....	Dunkirk, N. Y.
Harding, B. R.....	R. & G. Rd.....	Raleigh, N. C.
Hanson, C. F.....	D. & M. Rd.....	Detroit, Mich.
Hatswell, T. J.....	F. & P. M. Rd.....	East Saginaw, Mich.
Johann, Jacob.....	T. W. & W. Rd.....	Springfield, Ill.
Jackman, J. A.....	C. A. & St. L. Rd.....	Bloomington, Ill.
Jeffery, E. T.....	I. C. Rd.....	Chicago, Ill.
Johnson, J. D.....	C. & A. Rd.....	Chicago, Ill.
Kinsey, J. I.....	L. V. Rd.....	Easton, Pa.
Kelly, Jos.....	P. & W. Rd.....	Providence, R. I.
Kerr, Thomas.....	C. & A. Rd.....	Bordentown, N. J.
Keeler, Sanford.....	F. & P. M. Rd.....	Marquette, Mich.
Kidder, B. H.....		Buffalo, N. Y.
King, Robert.....	C. C. & A. Rd.....	Columbia, S. C.
Kilby, G. S.....	C. & P. Rd.....	Lyndonville, Vt.
Losey, Jacob.....	L. N. A. & C. Rd.....	New Albany, Ind.



NAME.	ROAD.	ADDRESS.
Lewis, C. M.	N. C. Rd.	Baltimore, Md.
Lauder, J. N.	N. Rd.	Concord, N. H.
Landis, H. D.	B. & S. S. Rd.	Bellefonte, Pa.
Leech, H. L.	Hinkley Locomotive Works	Boston, Mass.
Lininger, W.	P. V. & C. Rd.	Pittsburgh, Pa.
Lingle, Thomas.	C. & O. Rd.	Richmond, Va.
Lewis, W. H.	D. L. & W. Rd.	Hoboken, N. J.
Lewis, W. H.	N. P. Rd.	Brainerd, Minn.
Lannon, Wm.	W. M. Rd.	Union Bridge, Md.
Ladd, J. J.	P. & P. Rd.	Peru, S. A.
Lamb, James	C. B. & Q. Rd.	Galesburg, Ill.
LaSeur, W.	F. N. S. & C. Rd.	College Point, L. I.
Moore, S.	P. Ft. W. & C. Rd.	Allegheny, Pa.
Mulligan, J.	C. R. Rd.	Springfield, Mass.
Mitchell, A.	W. Div. L. V. Rd.	Wilkesbarre, Pa.
McKenna, J.	I. P. & C. Rd.	Peru, Ind.
McAllister, W.	W. J. Rd.	Camden, N. J.
McFarland, Jas.	M. & M. Rd.	Montgomery, Ala.
McFarland, John.	C. & O. Rd.	Richmond, Va.
McCrum, J. S.	M. R. Ft. S. & G. Rd.	Kansas City, Mo.
McDougall, R.	M. C. & O. Rd.	Whistler, Ala.
McVey, John.	W. Rd. of A.	Montgomery, Ala.
McKinzie, John.	H. & St. Joe Rd.	Hannibal, Mo.
Martin, J. E.	C. C. & T. Rd.	Chili, S. A.
Morse, G. F.	Portland Locomotive Works	Portland, Maine.
Mead, L. T.	C. F. & W. Rd.	Chippewa Falls, Wis.
Morgan, J. B.	C. D. & V. Rd.	Danville, Ill.
Morris, C. R.	Housatonic Rd.	Falls Village, Conn.
Metzger, Chas.	L. C. & L. Rd.	Louisville, Ky.
Morse, J. B.	T. W. & W. Rd.	Fort Wayne, Ind.
McDowell, R.	B. D. Rd.	Lambertville, Pa.
Noble, L. C.	H. & T. C. Rd.	Houston, Texas.
Noyes, Warren.	E. Div. G. T. Rd.	Gorham Station, N. H.
Orton, John.	G. W. Rd.	Hamilton, Can.
Osborne, Ezra.	Grant Locomotive Works	Paterson, N. J.
Pendleton, M. M.	S. & R. Rd.	Portsmouth, Va.
Perry, F. A.	C. & A. Rd.	Keene, N. H.
Perry, G. W.	Late P. W. & B. Rd.	Wilmington, Del.
Philbrick, S. M.	L. L. & G. Rd.	Lawrence, Kansas.
Perrin, P. J.	Taunton Locomotive Works	Taunton, Mass.

NAME.	ROAD.	ADDRESS.
Prescott, A. J.	D. G. R & I. Rd.	Logansport, Ind.
Peddle, C. R.	T. H. & I. Rd.	Terre Haute, Ind.
Philbrick, J. W.	M. C. Rd.	Waterville, Maine.
Prescott, G. H.	P. C. & St. L. Rd.	Logansport, Ind.
Purves, T. B.	W. Div. of B. & A. Rd.	Greenbush, N. Y.
Place, T. W.	I. C. Rd.	Waterloo, Iowa.
Potts, J. D. W.	O. & M. Rd.	Seymour, Ind.
Ray, W. F.	T. W. & W. Rd.	Fort Wayne, Ind.
Richards, George	B. & P. Rd.	Boston, Mass.
Roop, F.	N. P. Rd.	Philadelphia, Pa.
Robinson, W. A.		Hamilton, Canada.
Ross, Anthony	M. & C. Rd.	Memphis, Tenn.
Robb, W. D.	L. P. & S. M. Rd.	Elizabethtown, Ky.
Somers, A. H.	P. Ft. W. & C. Rd.	Valparaiso, Ind.
Strode, James	E. & C. Div. N. C. Rd.	Elmira, N. Y.
Stevens, G. W.	L. S. & M. S. Rd.	Elkhart, Ind.
Skidmore, J.	T. N. & G. S. Rd.	Nashville, Tenn.
Shaver, D. O.	Pennsylvania Rd.	Pittsburgh, Pa.
Smith, W. F.	C. C. C. & I. Rd.	Cleveland, Ohio.
Sellers, Morris		No. 6 Ashland Block, Chicago, Ill.
Setchel, J. H.	L. M. Rd.	Cincinnati, O.
Sellars, L. H.	N. O. St. L. & C. Rd.	Water Valley, Miss.
Smith, W. T.	P. & E. Rd.	Erie, Pa.
Sedgley, James	L. S. & M. S. Rd.	Cleveland, Ohio.
Strong, W. M.	N. Y. & H. Rd.	New York City.
Sanborn, A. J.	I. & St. L. Rd.	Mattoon, Ill.
Stearns, W. H.	C. R. Rd.	Springfield, Mass.
Sterk, F.	V. & T. Rd.	Lynchburg, Va.
Stewart, C. E.		819 Grove st., Eliza- beth, N. J.
Slingland, N.	Western Rd.	Hartford, Conn.
Sprague, H. N.	Porter, Bell & Co.	Pittsburgh, Pa.
Steinberger, Samuel	J. M. & I. Rd.	North Madison, Ind.
Salisbury, L. B.	St. L. & S. E. Rd.	Mt. Vernon, Ill.
Schlacks, H.	I. C. Rd.	Chicago, Ill.
Strattan, G. W.	Pennsylvania Rd.	Altoona, Pa.
Thompson, J.	P. Ft. W. & C. Rd.	New Lebanon, Ohio.
Thompson, C. A.	L. I. Rd.	Hunter's Point, L. I.
Thompson, John	Eastern Rd.	Boston, Mass.

NAME.	ROAD.	ADDRESS.
Turreff, W. F.....	L. S. & T. V. Rd.....	Black River, Ohio.
Towne, H. A.....	N. P. Rd.....	Brainerd, Minn.
Taylor, J. K.....	O. C. & N. Rd.....	Boston, Mass.
Tier, G. H.....	L. S. & M. S. Rd.....	Norwalk, Ohio.
Tull, C. H.....	N. L. & T. Rd.....	Monroe, La.
Underhill, A. B.....	B. & A. Rd.....	Boston, Mass.
Van Vetchen, J.....	Erie Rd.....	Susquehanna, Pa.
Van Buskirk, W. G ..	D. & C. Rd.....	Fishkill, N. Y.
Walsh, Thomas.....	M. & O. of L. & N. Rd .....	Memphis, Tenn.
Warren, B.....	St. L. A. & T. H. Rd.....	St. Louis, Mo.
Wallace, W. L.....	L. S. & M. S. Rd.....	Buffalo, N. Y.
Wallace, H. S.....	Late C. & H. V. Rd.....	Columbus, Ohio.
Woods, H. E.....	C. R. I. & Pac. Rd.....	Rock Island, Ill.
Whitney, H. A.....	Intercolonial Rd.....	Moncton, N. B.
Wells, Reuben.....	J. M. & I. Rd.....	Jeffersonville, Ind.
Wiggins, J. E.....	M. K. & T. Rd.....	Hannibal, Mo.
Waite, F. A.....	B. & M. Rd.....	Boston, Mass.
Wilder, F. M.....	Erie Rd.....	Buffalo, N. Y.
Wood, M. P.....	.....	32 Warren street, New York City.
Wills, J. C.....	T. W. & W. Rd.....	Lafayette, Ind.
Woodcock, W.....	Central Rd. of N. J.....	Elizabethport, N. J.
White, J. L.....	E. & C. Rd.....	Evansville, Ind.
Williams, E. H.....	Baldwin Locomotive Works.....	Philadelphia, Pa.
Waugh, L. H.....	K. P. Rd.....	Armstrong, Kansas.
Weaver, D. S.....	E. K. Rd.....	Hunnewell, Ky.
Walls, Martin.....	P. & E. Rd.....	Sunbury, Pa.
White, Philip.....	C. & P. Rd.....	Wellsville, Ohio.
Woodruff, T. B.....	C. Rd. of Iowa.....	Eldora, Iowa.
Wallace, Robert.....	Erie Rd.....	Susquehanna, Pa.
Young, L. S.....	C. C. C. & I. Rd.....	Cleveland, O.

## ASSOCIATE MEMBERS.

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NAME.	ADDRESS.
Bement, W. B.....	21st and Callowhill streets.....Philadelphia, Pa.
Dudley, P. H.....	Cleveland, Ohio.
Evans, W. W.....	63 Pine street.....New York City.
Forney, M. N.....	Railroad Gazette,.. ..73 Broadway, N. Y.
Holly, A. L.....	Troy, New York.
Lilly, J. O. D.....	Indianapolis, Ind.
Miles, F. B.....	Philadelphia, Pa.
Morton, Henry.....	Hoboken, N. J.
Nott, G. H.....	Boston, Mass.
Rogers, J. G.....	Madison, Ind.
Sellers, Coleman.....	Philadelphia, Pa.
Thurston, R. H.....	Professor at Stevens' Institute....Hoboken, N. J.
Wheelock, Jerome.....	Worcester, Mass.

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## HONORARY MEMBER.

Dripps, Isaac ..... 3405 Walnut street.....West Philad'phia, Pa.

### ORDER OF BUSINESS.

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1. Reading the Minutes of previous meeting.
2. Calling the Roll of Members.
3. Signing the Constitution.
4. Report of Secretary.
5. Report of Treasurer.
6. Report of Committees appointed at a previous meeting.
7. Election of Officers.
8. Appointment of a Committee to suggest Subjects for Consideration.
9. Appointment of Miscellaneous Committees: on Finance, Printing, and Place for holding next Annual Meeting.
10. Report of Committee to suggest Subjects for Consideration.
11. Appointment of Committees to report upon Subjects suggested for Consideration.
12. Unfinished Business.

H. M. BRITTON, N. E. CHAPMAN, W. A. ROBINSON, S. J. HAYES, J. H. SETCHEL,	}	Committee.
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## APPENDIX.

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It will be remembered that at the Ninth Annual Meeting a lengthy discussion was had upon the relative merits of the ordinary eight-wheel and the heavier classes known as the Mogul and Consolidation Engines for freight service.

The point made by those favoring the Consolidation engine was that, on account of the great adhesive power and boiler capacity, much larger trains could be hauled, and thereby a large saving in train hands and in the number of locomotives required to do the work would be effected; and, on the other hand, it was as strongly urged that the increased friction, on account of the extended rigid wheel base, the wear and tear to cars consequent to drawing these long trains, together with the destruction to the track, more than equaled any saving in this direction.

The advocates of the Consolidation engines deny the existence of any extra friction, and it being known that some extensive experiments had been made by Mr. Dripps, of the Pennsylvania Railroad, to determine this question, the Secretary was instructed to write this gentleman and obtain from him the result of the tests made. These were kindly furnished, and will be found duly recorded in another part of this report. About the same time the Secretary also received a detailed statement of a series of experiments made on the Boston & Albany Road, extending over a period of thirty-seven days, to test the capacity and economy of two of their own ordinary eight-wheel engines with a Mogul engine, built by the Rhode Island Locomotive Works, with a result decidedly favorable to the Company's build of engines. The point at issue being between heavy and light engines and the difference between the two classes of engines being given, and also the points peculiar to the Boston & Albany build of eight-wheel engines, the Secretary has taken the liberty to include this test in an Appendix to this report, thinking it

would at least interest the members and might lead to the development of some ideas in locomotive construction that, although long held by some good Master Mechanics, have not been generally thought to be correct, but which in this case must have had an important bearing or else the claim of superiority of the Mogul or Consolidation engine over ORDINARY eight-wheel engines is not well founded. It affords a striking illustration of the wide discrepancy existing between theory and practice, to see one of the oldest and best constructed lines of the country adopting the largest class of engines known, drawing trains of a hundred cars, which must require heavier rails and heavier cars, as the best and most economical power for conducting a heavy traffic; and, on the other hand, speculation running wild over imaginary dividends from narrow guages, run with engines so light that to do the work of a first-class road engines and trains instead of *cars* in a train must be numbered by the hundred.

The following is the experiment alluded to:

"The recent trials of locomotive engines upon the Boston & Albany Railroad has excited considerable attention among railroad men, and questions have been put by them as to the peculiarities and conditions of the competing engines; and we here give, as near as we can, the relative forms and proportions of the parts that are thought to bear upon the general result. One of them, the Brown, is an ordinary Mogul engine, having three pairs of driving wheels, and a single pair of guiding wheels, was built by the Rhode Island Locomotive Works, from specifications furnished by the Boston & Albany Railroad Company, and is about three years old.

"The other two engines, the Virginia and Adirondack, were of the ordinary eight-wheel kind, having two pairs of driving wheels, and a four-wheel truck, were built at the shop of the Boston and Albany Railroad Company, at Springfield, by Mr. Wilson Eddy, Master Mechanic, and have peculiarities long since adopted and adhered to by him. The Virginia new, and the Adirondack about three years old. All the engines were put in complete order by parties most interested in them, and also run by men most disposed to do them justice.

"The cylinders of all were the same size,  $18 \times 26$ ; the driving wheels were also the same diameter, 4 feet 6 inches, except those of the Virginia, which were 5 feet.

"The boilers differing in these particulars: The furnace of the Brown was  $65\frac{1}{2}$  inches long, 35 inches wide, and  $56\frac{1}{2}$  inches deep; tubes, 162, 2 inches diameter, 11 feet and 4 inches long. Those of the Adirondack and Virginia 54 inches long,  $41\frac{1}{2}$  inches wide, and  $51\frac{1}{2}$  inches deep; tubes, 162, 2 inches diameter, and 11 feet and 10 inches long. So it will be seen that as

to area of grate there were 60 square inches difference in favor of the Brown, and 42 square feet in flues in favor of the Virginia and Adirondack. The weight of the Brown is 73,600 pounds, 55,200 pounds upon the driving wheels. The Virginia and Adirondack 67,150 pounds, and 43,000 pounds upon the drivers.

"The marked differences are in these particulars: The Brown has the ordinary form boiler, with steam dome and dry pipe. The Adirondack and Virginia have straight top boilers, without dome, with perforated steam pipe, throttle valve in smoke box. The distinctive differences between these engines is thought to be in the steam ports, those of the Brown being 14 inches long and  $1\frac{1}{8}$  inches wide; those of the others 10 inches long and  $1\frac{1}{8}$  inches wide.

"At the first trial on the Western Division, between the Brown and Virginia, the Brown had valves with  $\frac{5}{8}$  inch outside lap, no inside lap. On the second trial on the Eastern Division, and also the third on the Western Division, the valves of the Brown were changed to  $\frac{3}{4}$  inches outside and  $\frac{5}{16}$  inch inside lap. The valves of the others have all along had  $\frac{3}{4}$  inch lap outside, and cut out  $\frac{1}{16}$  inch lead on each end inside. The throw of valves were in both cases 5 inches.

"On the first trial between the Brown and Virginia, five round trips were made between Greenbush and Pittsfield, 105 full loaded line cars were taken east, and 175 (a large number of which were empty) were taken west by each engine. The fuel consumed by the Brown was 30,850 pounds of coal, costing \$107.97. By the Virginia, 23,924 pounds, costing \$83.73.

"On the second trial between the Brown and the Adirondack, nine round trips were made between Springfield and Boston, 224 cars, less 24 from Worcester to Boston were taken east, and 320 less 5 from Worcester to Springfield, west by the Brown; and 223 east and 307 less 3 from Worcester to Springfield west by the Adirondack. The fuel consumed by the Brown was 106,150 pounds, costing \$371.00; by the Adirondack, 83,090 pounds, costing \$290.00. The average time upon this trial was (going east) to Charlton Summit, 1 hour and 4 minutes each trip in favor of the Adirondack; and from Boston to same summit, 1 hour and 39 minutes in favor of same engine. On the third trial between the same engines, 14 round trips were made between Greenbush and Pittsfield; 317 full loaded cars were taken east, and 387 west by the Brown; 317 cars east and 372 west by the Adirondack. The fuel consumed was 86,148 pounds coal by the Brown, costing \$301.54; and 69,676 pounds, costing \$226.36, by the Adirondack.

"Thus, it will be seen that in the 37 days' trial, the Mogul burnt 225,148 pounds of coal, costing \$790.54; Springfield engines, 176,690 pounds, costing \$600.11. In favor of the latter, 48,458 pounds, and \$190.43.

"Now, the question naturally arises, what has caused the difference in consumption of fuel and consequent expense? No doubt, in this particular, engineers will differ, but here it is not considered to arise from any particular feature alone, but from a combination of them, co-operating to the same end.



"First, the Springfield boiler is known to be a free and liberal steamer with ample steam room. The furnace is wider and shorter, which brings all parts of it within reach of the fireman, so that he can put the coal where he wants to without throwing it. Then the perforated steam pipe, which takes steam from and directly over the point where it is made, is supposed to have considerable effect upon the dryness of the steam used. The throttle in the smoke box as close as possible to the cylinders, allowing the steam to accumulate in the pipes and chest to a higher pressure, during the interval when both valves are closed, is believed to act favorably upon the economical expansion of the steam.

"The smaller valves and ports are believed to be of great importance (not that they should be unduly contracted); 'but only this.' They should be just large enough, for it is considered that a valve, unnecessarily large, will make an unnecessary friction, and will waste the difference of contents of the port at every exhaust, and will act severely upon the fire.

"On the other hand, the competing engine was a Mogul, with an additional pair of driving wheels and weight, with a proportional addition of friction of parts. The eccentric rods were short and gave a large addition of lead when linked up. In other respects it is so much like the ordinary standard of engines of its class, that we need not give the particulars. We here leave the *Engineering World* to speculate upon it as they will. And no doubt much good will come out of these elaborate and exhaustive trials."

The circulars of the Committees on Locomotive Tests and Purification of Feed Water having been received are also included in the Appendix, and the Secretary would respectfully recommend that hereafter the circulars of all committees be inserted in our Annual Report with the list of committees and subjects for discussion. This arrangement will distribute the circulars to the members in better time, and secure their preservation for future reference, and will be quite a saving in expense of printing and postage.

Very respectfully,

J. H. SETCHEL, *Secretary.*

The Committee appointed by the American Railway Master Mechanics' Association, to report on the Purification of Feed Water and Formation of Boiler Incrustations, present the following questions:

**Effect of Incrustations on Consumption of Fuel.**

1st. How many miles per ton of coal do engines with clean boilers average on your road?

2nd. How many miles per ton with boilers from which incrustations have not been removed?

3rd. What do you estimate the loss to be in money, per year, for fuel used on account of formation of scale in boilers on your road?

**Effect on Life of Furnace Sheets and Outside Shell and of Flues.**

1st. To what extent, in your opinion, is the life of a copper, iron, or steel furnace shortened by the formation of scale in boilers on your road?

2nd. To what extent is the life of flues shortened by the same cause?

3rd. In what manner do incrustations affect the sheets in outside shell of boiler, and to what extent is the service of such sheets lessened by the action of incrustations.

**Remedies and their Cost.**

1st. What is the cost, per engine per year, on your road for removing the incrustations from locomotive boilers?

2nd. What so-called anti-incrustators and boiler compounds have you tried for removal or prevention of boiler incrustation?

3rd. Have any proved successful, and if so what are they?

4th. What does it cost, per engine per year, to use those which proved beneficial?

5th. Have you tried any plan for purifying feed water for locomotive boilers, and if so please describe it and state the cost of the process per one thousand gallons of water purified?

Please reply before March 1st, 1877, addressing the Chairman of Committee, E. T. JEFFERY, Assistant Superintendent Machinery Illinois Central Railroad, Chicago, Illinois.

E. T. JEFFERY, *Illinois Cent. R. R.*  
H. L. COOPER, *I. B. & W. R. R.*  
J. C. WILLS, *T. W. & W. R. R.* } *Committee.*

To———, Esq.,

M. M. ———, R. R.:

DEAR SIR—The undersigned, a Committee appointed at the last Annual Convention of the American Railway Master Mechanics' Association, to report on the subject of

**Locomotive Tests,**

respectfully desire the co-operation of members of the Association in furnishing to them any record of tests they have made, or may make, prior to next Annual Meeting.

1st. Comparative tests of several classes or kinds of locomotives, as to number of cars hauled by each class, giving weight and dimension of each

class; pressure steam carried; kind and quantity fuel consumed; miles run; kind of exhaust, single or double nozzle; diameter nozzle; condition of road, grades, curves, etc.

2nd. Have you made any tests in burning fuel in locomotives; and what kind gives best results as regards economy? State whether plain fire box, water table, or brick arch was used? If convenient, please give sketch of same, including stack and arrangement in smoke box.

3rd. Give results of any tests of a general character, that will be of interest and value to the Association.

The Committee desire the members to give the Association the benefit of their experience relative to the above subject, that it may be placed on record for reference. A blank form is here appended, in which the weight and dimensions of engines can be conveniently entered.

Very respectfully,

WM. WOODCOCK, *M. M., C. R. R. of N. J.*  
S. A. HODGMAN, *M. M., P. W. & B. R. R.*  
DAVID CLARK, *M. M., L. V. R. R.* } *Committee.*

Please address replies to WM. WOODCOCK, Master Mechanic Central Railroad of New Jersey, Elizabeth, N. J.

Dimensions and Weight of Locomotive Experimented with on the ——— Railroad, by ———, Master Mechanic, date ———, 187—: Description of locomotive; number of driving wheels, truck wheels; length of driving wheel base; total driving wheel base; total weight of engine in working order, pounds; total weight on driving wheels in working order, pounds; total weight on truck wheels in working order, pounds; total weight of water in boiler, pounds; diameter of driving wheels; diameter of cylinders, stroke; size of steam ports, exhaust ports; greatest travel of valve, lead in full gear; outside lap of valve, inside lap; length of grate, width; height of fire box; tubes, number, diameter, length, material; heating surface in fire box, in tubes, total; exhaust nozzles (single or double), diameter; diameter of inside pipe in smoke stack. Remarks.

